The Art of Irrigation

The Development, Stagnation, and Redesign of Farmer-Managed Irrigation Systems in Northern Portugal

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Preface

With the writing of this preface a long journey is coming to an end, an intellectual adventure with many standstills, paths ending in swamps, mountain tracks that make you hesitate to go on but at the same time offer you glimpses of beautiful *vistas*. I found my research in Trás-os-Montes demanding. Trained in irrigation engineering with professional experience in project management, design and implementation of irrigation projects, becoming involved in proper research activities was surely not evident for me. Only armed with curiosity I had to learn much: making research proposals, writing skills, understanding and coming to grips with theories from the social sciences. At the same time I found it very rewarding. The research in Trás-os-Montes has definitely changed my understanding and thinking on rural development and irrigation.

During this journey I met many people which helped me to bring it to a successful conclusion. I owe a lot to them. In the beginning it was particularly the late Jacques Slabbers and Paul Hoogendam from the Department of Irrigation and Soil and Water Conservation at the Wageningen Agricultural University who introduced me to the essentials of doing research and supported me in the development of research skills.

At the *Departamento de Economia e Sociologia* of the *Universidade de Trás-os-Montes e Alto Douro* in Vila Real I found a highly appropriate environment for my research work. I had a very fruitful collaboration with Prof. José Portela. I am impressed by his commitment to contribute to the development of the marginalised Portuguese countryside based on a deep understanding and a encyclopedic first-hand knowledge of all aspects of Portuguese rural society, particularly that of Trás-os-Montes. I would also like to mention the staff members Artur Cristóvão, Alberto Baptista, Vasco Rebelo and Timothy Koehnen for their encouragement and support in various aspects.

Henk Oostindie, researcher of the agrarian reality and diversity in Barroso, and Cathe Kwakkenbos, interpreter-translator of Portuguese, were already there when I arrived in Vila Real. We became good friends during our stay in Trás-os-Montes. To Henk I owe much of the statistical analysis underlying the comparison of two contrasting farming patterns in Chapter 5 and much food for thought.

Without the 'cave' people, life would have been less enjoyable and funny. It was a great pleasure to work and collaborate with this heterogeneous and changing group of research assistants and Portuguese and Dutch MSc students who, through inventory and case studies contributed much to the research on irrigation and agrarian development in Trás-os-Montes. In that connection I would like to mention Miguel Malta, Paulo Morgado, Nuno Gusmão, Michiel Kuik, Hans Bleumink, Victor Morgado, Fernando Pereira, Merlijn Izarin, Moniek Stam, Julia de Carvalho, Frans Schultink, Carlos Marques, Eline Boelee, Maria Cordeiro, Erik Prins, Jako Verstraate, Riens Middelhof, Hugo Hoofwijk

and Arjan Budding. The value of their work will be clear from the reference made to it in different chapters of this book.

Many times my thoughts go back to these special, industrious and hospitable people I met in the villages of Trás-os-Montes, thinking how they are going. Without their willingness to share their experiences and ideas this book could not have been written.

Back in Wageningen, I worked on a semi-regular basis as a lecturer at the Irrigation and Water Engineering (IWE) group. Apart from the open and collaborative atmosphere I had the opportunity to learn a lot from staff members and students. I thank you all.

Without the special mix of trust, encouragement and patience shown by Jan Douwe van der Ploeg this book would not have been written. He lifted me various times out of the swamps where I got stuck in the mud and seized by a sense of triviality. He challenged me always to 'think deep'. I learned much from his mastery in linking the general to the detail, theory to practice, the 'social' to the 'material'.

I owe to Han Stricker and Piet Warmerdam of the Department of Hydrology and Hydraulics (Wageningen University) the suggestion to use the salt dilution method for measuring canal discharges in Trás-os-Montes conditions and some logistical support for the implementation of this method. Bert Tolkamp and Hans Schiere of the Department of Zootechnics (Wageningen University) offered their help in the estimation of metabolic energy production and requirements, dealt with in Appendix II. Ruurd Koopmans of the Department of Hydrology and Hydraulics (Wageningen University) gave me some support in the mathematical analysis presented in Appendix IV.

I appreciated much the comments of Maurits Ertsen, Flip Wester, Rutgerd Boelens and Marjan Stuiver on earlier versions of Chapter 1.

I am grateful to Jeroen Warner (correction of English), Jaap Bijkerk (figures) and Ans van der Lande (text layout and preparation for publication) who improved significantly this thesis. Eulália de Araújo and Cathe Kwakkenbos contributed much to the Portuguese summary (*Resumo*). Berend Boer and Ko ter Hofstede supported me in writing and correcting the Dutch summary (*Samenvatting*).

Finally, I want to thank a minha querida Cecilia for her patience to endure my stress in finalising this thesis.

1 Introduction: Some Theoretical Notes

In this book I aim to discuss an example of skill-oriented technology. The example is located in Europe, that is in the Trás-os-Montes region in Northern Portugal. Skill-oriented technologies, characterised by the combination of relatively *simple* instruments and *highly sophisticated* knowledge to operate these instruments, represent, at first sight, an anomaly, a reference to the past, at least in Europe. In current opinions reigning within state apparatuses and scientific circles, such technologies, being so tightly associated with and indicative for peasant societies, do not represent the way forward. In this view it is precisely these technologies that need to be replaced in order to modernise the agricultural sector. I feel uncomfortable with such views. In this book I will develop the thesis that there is a considerable potential entailed in skill-oriented technologies, here embodied in farmer-managed irrigation systems, which can be developed further.

This chapter will describe the most important theoretical concepts I will use to order and interpret the empirical reality of farmer-managed irrigation in Trás-os-Montes. Historically, these irrigation systems were created and developed by local actors in response to local farming needs. Each particular system emerged and developed in a specific local context, characterised by three fundamental dimensions: the physical environment, the social relations of production and the agricultural setting. This poses the question of the functioning of these systems and the context in which they are embedded. However, during the last decades the context (as a consequence of emigration, entrance of Portugal into the EU etc.) in which they are operating is changing profoundly. Related to these changes, development projects have been introduced which stimulated new farming development patterns. Thus relevant questions emerge: what is the role of irrigation in traditional and new farming patterns? What are the different requirements of these farming patterns related to irrigation practices? The changing context sketched above raises the questions of how farmer-managed irrigation is developing, how the irrigation systems are adapting to new circumstances, how public irrigation interventions could be characterised and what is the potential for the improvement of the Farmer-Managed Irrigation Systems (FMIS). In a nutshell, these are the questions that will be discussed in this book.

Instruments, knowledge and technology

In any labour process one might distinguish three basic elements: the objects of labour, the instruments and the labour force (van der Ploeg 1991; Lacroix 1981). The objects of labour are those elements that are converted into intermediate or end products, for instance a cow producing milk or a plot with potato seedlings producing potatoes. Also, irrigation water can be considered an object of labour, for instance in the form of an irrigated meadow producing hay. Instruments are those elements used to facilitate and/or improve the labour process. A tractor, a pair of oxen, a computer but also an irrigation system might be considered such instruments. Finally, the labour force – this category evidently refers to those directly involved in the process of production.

Once these three elements are combined and set in motion it can be considered a labour process, which is identical to a production process. It goes without saying that putting in motion the indicated elements requires careful co-ordination. The labour force needs to be thoroughly familiar with the labour objects and instruments. The actors involved in the labour process need to be carriers of 'local knowledge' (Mendras 1970; Darré 1985; Leeuwis 1993), that is, the know-how concerning the required and most appropriate use of the concerned instruments and labour-objects. '*Savoir faire paysanne*' (Lacroix 1981) concerns above all the best ways to deal with the locally available instruments and objects of labour.

Further, the instruments need to correspond with the objects of labour. To give just one illustration: the lay-out and the operation of an irrigation system have to correspond with the crops and soils to be irrigated. Crops and cropped areas have to correspond with water availability and its variability during the agrarian calendar. Knowledge is again crucial here. Those who irrigate have to know about the crops, their water requirements, their drought resistance, their rooting characteristics. They need to know about the soil and its water retention properties, the land, with its topography, unevenness, however small the plot may be[1].They also have to know the characteristics of the irrigation system and the way to 'control the water'. And above all: they have to be able to integrate and co-ordinate these different 'blocks' of knowledge. How to irrigate a particular plot with a specific crop is an example of the combination of these 'blocks' of knowledge. One needs to adjust many mutually interrelated elements such as the topography, the size and the lay-out of the plot, the characteristics of soil and crop, the timing and length of irrigation turns, the size of the irrigation flow and the labour input, to name but the most important elements.

More generally speaking, it is only through the combination of a specific artefact and the knowledge regarding its use that a technique or technology emerges. Without this knowledge any artefact (be it an irrigation system, a tractor or a computer for automated cattle feeding) remains useless. It is only through the required '*savoir faire*' that it is turned into an instrument, into a technique or technology to set into motion a particular process of production.

Skill-oriented vs. mechanical technologies

In an impressive review of 'Asian Rice Economies', Bray (1986) develops two concepts that appear to be strategic for the study of many farming systems. These are *skill-oriented technologies* and *mechanical technologies*. The difference between the two concepts regards the combination of knowledge and instrument. In skill-oriented technologies we are faced with relatively simple instruments that are managed with impressive, far-reaching and detailed local knowledge that takes the conditions, goals and particularities of the concerned labour process into account. In the case of mechanical technologies it is exactly the other way around. The instruments are highly sophisticated (and mostly they are produced by actors other than the involved farmers), whilst the knowledge needed to operate or manage them (which is different from the knowledge needed to produce them) is relatively simple.

To take an example by van der Ploeg (1991:189-198; see also Akkerman 1994): to work with a *radu*, at first sight an astonishingly simple instrument to work the land, requires tremendous skills which could only be learned by experience. Instead, the knowledge to operate a central pivot[2] – once well installed[3] – is relatively simple. When, moreover, irrigation scheduling is contracted out to external irrigation advisors, for instance in certain areas in the USA, the required knowledge is even reduced to pushing two or three buttons in the correct order. To give another example: preparing a plot for surface irrigation and irrigating with a hoe requires considerable skills and experience. On the contrary a simple instruction is sufficient to enrol driplines. In her study Bray (1986) develops many similar illustrations.

However, I think that a problem of this distinction between skill-oriented and mechanical technologies is its dichotomic character. It suggests a false contradiction. Also operating sophisticated agricultural machinery could require considerable skill and experience, i.e. supposes a combined detailed knowledge of the task to execute, of crop properties, local conditions (soils, weather), the machine, its use and the possibilities of adjustment to these conditions. For instance to operate a laser-guided scraper could seem an easy job but the best operators (with respect to efficiency and quality) are those who could do the same work without laser guidance (pers. comm. Martien Damen).

This dichotomy is somewhat modified by van der Ploeg (1999). He developed the meaning of these concepts further by applying them to different patterns of farm development (van der Ploeg 1999:112) in the same context. Then, this distinction offers an important clue in understanding technological development and the organisation of production pointing to different sets of relations between instruments, objects of labour and the labour force.

The distinction between skill-oriented vs. mechanical technologies is a fundamental dimension enclosing different unfolding possibilities in farm development. Diverging modes of ordering or styles of farming[4] could be centred around these distinct technologies (van der Ploeg 1999:112). In the styles of farming focussed on the use of instruments the main goal is to increase the scale of production (more objects of labour per labour unit). This often induces a preference for ‘mechanical’ technology. In the concept of skill-oriented technologies the object of labour is central. Intensive production (high output per object of labour) is pursued. Fine-tuning and precise work are crucial. Essential is the knowledge and experience regarding the objects of labour embodied in the labour force. Here, technology appears as an extension of labour (Wiskerke 1997:68), as a way to work better and more precise.

Skill-oriented and mechanical technologies are not simply interchangeable. They represent different development paths and are part and parcel of particular farming systems, neatly interwoven with the complex fabric that links labour force, instruments, objects of labour and the wider context in which farming is takes place: the eco-system (natural resources) and the social relations of production.

Equally it is to be stated, right from the beginning, that any attempt to construct an *a priori* ranking in terms of better and worse is to be avoided. It is in fact impossible: one cannot isolate techniques and technologies from the contexts in which they have emerged and are operating.

An impression of farmer-managed irrigation in Trás-os-Montes

The example of skill-oriented technology I set out to analyse here is composed of farmer-managed irrigation systems in the North of Portugal. Anyone who first learns about these irrigation systems cannot escape from the image of 'primitivity'. They are, at first sight, just cart-ruts carved out in the rocks or lost in the mud, tiny streams of water meandering through the meadows and old men and women walking around with their hoes. For me it was a great surprise. I am a trained irrigation engineer and before coming to Trás-os-Montes I had worked for more than 13 years in Mozambique and Nicaragua. Apart from that, through education, study and short missions, I familiarised myself more or less with different irrigation systems in the Philippines, Pakistan, Tunesia, Angola and Ecuador. And during my youth – I grew up on a farm in the Noord Oost Polder where drainage and irrigation are part of everyday life – I also learned a fair bit[5].

My first contact with irrigation in Trás-os-Montes was in mid-winter 1991-92 at Lamas d'Olo, a mountain village of approximately 100 households, some 14 kilometres from Vila Real, the capital town of the region.

The mountains were covered with snow and it was very cold and rainy. At the border of a small stream near the village a very wet meadow appeared in which water was flowing from a channel. I was struck by it. Grass growth was not possible because of low temperatures; there was no need for water at all. Why was it that those already very wet meadows were not drained to the stream but at the contrary irrigated in the winter?

Walking in the village area we came across one lined canal, product of a government intervention, in which no water was flowing. On both sides of this canal there were unlined channels transporting large flows. Other channels hardly deserve that name, they looked more like rough temporary sewers to get rid of excess water. In some of these channels much water was flowing, in others there was a small flow. Some channels were blocked with soil and stones at various places. No structure was present or even field inlets. At the inlets of some meadows we saw holes partially filled with sand, presumably primitive sediment traps. The configuration of the channels did not seem to have any logic to it at all and not to fit the conventional technical models. Some channels crossed each other at different levels so that the water from one channel did not mix with the other channel. In the conventional design of irrigation channel layout as taught at university departments and practised in engineers' offices such crossing of irrigation channels is considered nearly a mortal sin, a guarantee for confusion. Moreover, the functions of these channels were not clear: irrigation, drainage or both and some also functioning at the same time as cart paths, another confusion. Some channels ended in irregularly shaped earthen pools with very simple outlets covered by stones and compacted soil.

The local farmers explained the functioning of this confusing mix of simple infrastructures to us. Their explanation of the crossing of two channels was simply that the waters are different, the water in one channel belongs to ‘Antonio Pereira and his brother’ while the other channel is the *rego do povo* (literaly ‘people’s channel’) whose water belongs to all neighbours (*vizinhos*). That in this irrigation context the ‘one’ water is different from the ‘other’ water, opened a New World for me. Waters have different physical properties according to conventional technical wisdom, but these waters also have different properties in terms of ownership, although they may also have different physical properties relevant for irrigation practice, as I will show later. The farmers used also many local expressions which even my Portuguese colleagues did not understand, for instance *a pilha*, a type of water distribution that literally means ‘plundering’. For our informants everything they explained seemed self-evident and they reacted laconically to our questions.

In other villages the situation is still more complex, principally when numerous buried PVC tube lines make the relations between sources and destinations of water transport invisible.

Other surprising experiences I had in the village ‘Gallegos de Serra’ (lit. Galicians of the mountains). A farmer I was talking with, invited me to assist in irrigating his potato field. When we arrived there, a neighbour was irrigating his maize field. Then the farmer started to help the neighbour to irrigate. Later he explained that it was to receive the water more rapidly at his own field. His neighbour would give the water only at the moment his field was irrigated satisfactorily. What that meant was not that clear but apparently the farmer could influence that by helping the neighbour to spread the irrigation water more rapidly over the neighbour’s field so that he in turn would receive the water. In terms of conventional technical wisdom this is complete nonsense. Water supply has to be equal to crop water needs. Water supply is a combination of irrigation interval and irrigation depths. A certain irrigation depth corresponds to a fixed time period of constant flow rate entering the field. At any particular moment those parameters are clearly defined for a particular crop on a specific soil. What hell that a farmer could affect these parameters by helping his neighbour to irrigate!

In the same village I met a woman farmer at her field waiting for water from a channel. A short time before the water in the channel was to arrive at her field, she opened a reservoir on a higher plot from which the water also started to flow into the same channel. So she received on her field a mixed flow of original channel water and reservoir water during her turn. She explained that the channel water is from the *levada* (the collective irrigation canal) but the reservoir water is from the *herdeiros* (lit. heirs). She mixed the water of the reservoir with the channel water in order to irrigate more rapidly. It was self-evident for the woman, but for me it was an unknown reality that in the same area different water sources and irrigation facilities exist with different groups of users and moreover that they are overlapping. A water user could be a member of all these different groups and use the irrigation facilities of these groups at the same moment in certain periods but in other periods not. These complex networks of channels, reservoirs, water sources with different property regimes, scattered in the territory of the village which mix in certain places at certain times but not at other times and in other places, at first sight give a chaotic impression.

I came across many other surprises in these irrigation schemes. For instance, one plot in the middle of an irrigation perimeter with some 80 irrigated plots was not irrigated. There is a whole history behind that, with its own logic. Asked about the existence of an irrigation committee or water users association in a village, most people will stare at you and will not understand what you are talking about. They seem organised without organisation, to play a concert without a maestro. There is no constitution nor a set of written rules. When I, in a certain system, asked for a time schedule of irrigation turns someone responded: ‘here we are so practical that we don’t need that piece of paper’. But even users of the system did not seem to know completely how their system functions. Sometimes I received answers such as: ‘I don’t know when I will get water. Maria will have it first, then it will be my turn’.

But sometimes water is war. Until recently, conflicts about water were an important cause of death among Portuguese farmers[6]. Sometimes people told me in a malicious tone of voice how they or others, sometimes with the help of lawyers, managed to capture water sources originally belonging to or used by other persons. The stories were told with an abundance of local complexities and contextual details, some stories were very funny and considered proofs of cleverness. For instance, the story of a farmer who excavated a well but water did not appear; then he turned his eye to a nearby spring belonging to his neighbour and relied on an old local rule stating that when one digs a canal during the night and nobody protests before dawn, you have the right to use that canal as you wish; So one night he opened a ditch between the dry well and a nearby spring belonging to his neighbour, he filled the bottom of the ditch with stones making a type of drain, then he closed the ditch again with the excavated material. In this way he was able to capture the water of his neighbour without being discovered in time[7].

In August 1992 I was perplexed by a news story in the ‘Público’, a Portuguese newspaper. The pilot of a helicopter sought to collect water from an irrigation reservoir in order to fight a nearby forest fire. However, a married couple that was irrigating attacked the helicopter with stones, so that it was obliged to abandon the site. This is perhaps an extreme case but it illustrates well that water continues to be a resource with a high conflict potential . Endless struggles between neighbours about water have taken place and still do take place. In one village I knew a farmer who was involved in a silent struggle with his neighbour that had been going on for years. The farmer started to dig a pit on his plot for using ground water for irrigation. Then a farmer on a neighbouring plot dug a deeper pit and pumped the first pit dry. In response the farmer excavated his well deeper and dried up the other farmer’s well. Then other strategies also were deployed, for instance the buying of plots upstream of the original plots and opening pits there, obstructing the right of way, trying to involve other neighbours etc. This cycle of action and reaction repeated itself three times during the period I stayed in Trás-os-Montes.

The above impressions, observations and episodes could easily be multiplied, as will be demonstrated in the following chapters. But through these sometimes confusing experiences and apparent chaos I became familiar with these irrigation schemes and their underlying logic. In time, as my understanding of these systems increased, I experienced even a kind of aesthetic feeling.

The beauty of these irrigation practices and related systems has several dimensions. First, they are hardly visible, nor in infrastructure nor in management. They are an integral element of a complex farming system materialised in a very varied, particular landscape. This is in contrast with other irrigation systems whose standardised technical facilities and irrigated monocultures dominate and changed the landscape into a sometimes saddening monotony. Second, they are a clear illustration of the use of a natural resource in which farming and irrigation practices are perfectly adjusted to each other. The most appropriate agricultural use is made of water in conformity of its characteristics (availability, physical properties etc.). Third, they are highly functional systems, made by people to their own measure. Irrigation facilities are very simple. On the other hand, though, the management of the irrigation systems often seems highly complex to outsiders, although it is apparently self-evident for water users themselves. The functioning of the systems seems to be governed by an invisible, silent convenant of the concerned water users.

The effectiveness of these simple systems contrasts with the bad performance of many technically sophisticated (public) irrigation systems the whole world over and in Portugal in particular. The implementation of a whole range of technical and social engineering measures and fashions varying from rehabilitation, institution building, training courses, creation of water users associations to participatory approaches etc. has changed little to this state of affairs. What is it that made these simple systems in general to perform well, while others perform and continue to perform badly?

The social and the material

Concerning this question I want to discuss an element that seems relevant to me. It stems again from the varied if not contradictory impressions I obtained and gathered through my professional experience. It regards the way irrigation systems are managed. Such management is often highly complex. It has to ‘convert’, as I will explain further on, water allocation into physical distribution and concrete water use. The latter hardly follows automatically from the former. Through this management *the particularities of ‘the material’ are to be brought in line with those of the ‘social’*. And vice versa. *Co-production* (Callon *et al*. 1995; Latour 1994; Van der Ploeg 1997) is to be wrought.

The management of many Farmer-Managed Irrigation Systems in Trás-os-Montes, notwithstanding their tremendous degree of complexity, runs smoothly. The social and the material are, so to say, in line. The social is *not outside* the material – the social functions through the material. Let me try and explain the point underlying the obvious by making a reference to another experience from my professional career.

In 1991, I visited the Visayas Islands in the Philippines. The objective of the mission was a study of the feasibility of construction and rehabilitation of small irrigation systems. Some of them had already been rehabilitated some years before. In the framework of the project, intensive farmer participation was foreseen together with institution building, farmer’s committees, improvement of communication flows and other social engineering along with the introduction of an uniform cropping calendar. When I visited these systems I felt intuitively that these measures would not resolve the problems of these systems. I had the feeling that the crucial point was not addressed but at that moment I was not able to formulate this point. Later on I realised that *the key problem of any irrigation system, namely the control over and the access to a scarce resource as irrigation water*, was ignored. This led to the lack of a clear, reliable water distribution arrangement, the very heart of any irrigation scheme. In these systems water distribution seemed an *ad hoc* question, the object of daily and weekly meetings but not of underlying allocation principles, clear distribution rules and corresponding appropriate technical infrastructure. A crucial experience was an accidental visit to an irrigation system which was not in the project but adjacent to one of the project systems. There I met a very well-performing pump irrigation system with three rice harvests per year when the project systems achieved two with great trouble. I learned that the management of this system was very simple, based on a minimum number of clear rules. Contrary to the project schemes it had no (official) water committee, no uniform cropping calendar and the like. Each water user with land in the small irrigation perimeter has access to water whenever (s)he wanted. To effectuate this right (s)he needed to bring a small bidon of diesel fuel and a small amount of money (for renumeration and pump maintenance) to the pump operator. This allowed a considerable water flow during more or less 2.5 hours. After this time some shouting occurs and a big white flag is hoisted as a signal that it is the turn of the following water user in the row. And so on. All other arrangements were between the individual water users themselves.

FMIS in Trás-os-Montes are the opposite of the daily and weekly meetings as occurred in the systems I visited in the Philippines. They are more akin to the neighbouring system where a white flag seemingly suffices to run the system. Further on in this book I will discuss more or less identical systems. Systems that are so surprisingly simple (like ‘drawing a straw’) that one hardly believes that a complex world might be ordered in such a way at all.

Yet there is an underlying dimension which to me seems crucial: people (i.e. irrigating farmers) do not relate through weekly meetings but through the artefacts and the rules that together compose an irrigation system.

In any irrigation system there is an interplay between artefacts (the physical infrastructure), the rules and the context in which the irrigation system is functioning. The interrelated and mutual (mal)adjustment of these elements are determinants of the performance and sustainability of any irrigation system. It is the rules implemented and controlled by the users that makes ‘the material’ work, that makes an irrigation system function or disfunction. On the other hand, the artefacts determine to which extent rules can be materialised.

The crafting of institutions

Arriving at this point I think that Elinor Ostrom (1990, 1992) developed a set of highly relevant notions on institutions, which I will discuss here. The process of designing and developing working rules that participants understand, agree upon, and are willing to follow, is referred to by Ostrom as the crafting of institutions. She defines an *institution* as:

> *'the rules actually used (rules-in-use or working rules) by a set of individuals to organise repetitive activities that produce outcomes affecting those individuals and potentially affecting others. Hence, an irrigation institution is the set of working rules for supplying and using irrigation water in a particular situation'* (Ostrom 1992:19)[8].

Some elements contained in this definition are important to emphasise. First, a set of working rules is established in a particular situation and need not be appropriate in other situations. Working rules must be specific because of the great variety of physical, cultural, economic and social conditions that affect the operation of any particular system. That pre-supposes the use of local, place and time-dependent knowledge. Second, rules relate to each other, a set of working rules must be consistent, interrelations between working rules must be coherent. For instance, the rules that regulate the appropriation of water must be mutually adjusted to the rules that secure the initial construction and reproduction of the irrigation system[9]. Without a fair, orderly, and efficient method of allocating resource units, local appropriators have little motivation to secure the continued provision of the resource system (Ostrom, 1990:33). Third, these working rules are useless if they are not applied by the people that have designed and agreed upon them. This implies that working rules must be shared knowledge. Equally crucially, appropriate working rules must also meet the condition that they can be monitored and enforced in an effective and efficient way given the possibilities of breaking the rules[10]. *Only in this way rules provide stability of expectations*. Monitoring and enforcement of the rules, commitment to follow the rules and rule-making are inseparable elements. Some rules cannot be enforced because no one is able to monitor compliance with them (Ostrom 1990:35) Without monitoring, there can be no credible commitment; without credible commitment there is no reason to make (new) rules and vice versa (Ostrom 1990:45). In that respect some other concepts are very important. *Transaction costs* are the costs related to rule-making, co-ordination, monitoring and enforcement of the rules-in-use. Cheung (cited in Ostrom *et al*. 1993:71) defined transaction costs as *the costs of operating institutions*. In other words, in an irrigation context transaction costs are the costs, in the broadest sense, of managing irrigation. The lower the transaction costs, the more effective working rules are. When monitoring and sanctioning mechanisms become more expensive and/or benefits of water use are decreasing, for instance because of a changing context in which irrigation takes place, rules that once were effective could become obsolete. Rules have to be adjusted to a new reality. The related costs of change, that means the costs related to the making, agreeing and enforcing of new rules, are called *transformation costs* (Ostrom 1990:140).

Another important concept is *capital*. The development of FMIS, or more generally, irrigation development, can be considered the building up of capital. Three forms of capital can be distinguished: physical (infrastructure), human (skills) and social capital. The set of working rules can be viewed as social capital. Any irrigation system can be viewed as a unique combination of physical, human and social capital. The match of these elements, internally and with the context in which irrigation takes place ('are they in line?') determine the sustainability and performance of the irrigation system. The successful functioning of FMIS reflects enormous capital, not only its separate elements but principally the combination of these elements in the specific context in which the system is operating.

The term 'crafting' emphasises the skilful and ongoing nature of the institutional design process. Craftsmanship is involved in devising rules that both match the unique combinations of variables present in any one system and can adapt to changes in these variables over time (Ostrom 1992). In other words, to produce effective outcomes working rules must be embedded in a particular physical, socio-economic and cultural but changing environment. These working rules are not in place right from the beginning and developing them is a process of learning, trial and error. Rules must be matched to new circumstances and opportunities. To give a simple hypothetical example: the length of the irrigation interval is a very important parameter in an irrigation system because it defines the timing of irrigation applications and as such is one of the crucial factors which determine the variation of soil moisture in the root zone and consequently plant water stress. This parameter is the outcome of and interrelated with other rules that are, for instance, related to the applied quantity of irrigation water, which in turn is the outcome of the available water flow applied during a certain irrigation time. Suppose that at a certain point of time, for instance because of changing markets the production of vegetables (which in general have shallower root systems) becomes attractive, a need to change the irrigation interval could arise. This change implies that a series of other related rules also may need to be adapted. Because of the ongoing process of change, the process of crafting effective institutions never ends.

In many FMIS, farmers have crafted their own working rules together with the artefacts and the skills to operate them, without external assistance. The rules that are made, monitored and enforced by farmers themselves constitute farmer-governed irrigation institutions. Many of these systems are successful, principally for two reasons. First, these rules are adapted to the particular physical infrastructure, the environment and farmers' objectives. That means that within and between these irrigation systems rules are diverse and dependent on place and time. Second, transaction or management costs (the costs of co-ordination, monitoring and enforcement) are low in many FMIS as a result of the rules-in-use.

Allocation and distribution rules constitute a beautiful illustration. They stipulate the procedures and bases of water withdrawal. If this is not well defined, it leads to uncertainties in water deliveries and water rights which triggers a vicious circle of practices such as free-riding, rent-seeking and corruption. If proper allocation rules are adopted and effectively enforced, they can reduce uncertainty and conflict among irrigators (Tang *et al*. 1993). Because irrigation water is a subtractive resource, the withdrawal of a quantity of water by one farmer means that this quantity is not available for anyone else use. That is why allocation and distribution rules are especially important when the supply of water is inadequate to meet the water requirements of all cultivators simultaneously. In this situation rotational distribution is frequently practised in many

FMIS. This distribution mode assigns sequential fixed rotation times. Monitoring and enforcing this rule is astonishingly effective and efficient.

> *'Water rotation usually places the two actors most concerned with cheating, in direct contact with each other. The irrigator who nears the end of a rotation turn would like to extend the time of his or her turn (and thus the amount of water obtained). The next irrigator in the rotation waits nearby him or her to finish and would even like to start early. The presence of the first irrigator deters the second from an early start, and the presence of the second irrigator deters the first from ending late. Neither has to invest additional resources in monitoring activities. Monitoring is a by-product of their own strong motivations to use their turn to the fullest extent'* (Ostrom 1992:72, 73).

Many other rules in FMIS are self-enforcing and require minimal supervision. In that context I also refer to the already-mentioned episode of an irrigator helping his neighbour to irrigate in order to receive the water more rapidly himself. More examples will be given in Chapter 2 and 3. Problems arise, however, if the water flow is erratic: an irrigator owning a particular time share is still uncertain about his supply (Tang *et al.* 1993). This problem may occur in systems with two or more distribution levels that are not well-co-ordinated. In that case an irrigator who is assigned a time share of the flow in a minor canal may fail to receive any water if the stipulated water is not diverted at that time from the main or secondary channel to this minor canal. This uncertainty about water supply naturally affects the willingness of irrigators to co-operate in water distribution and maintenance[11].

In conclusion, the search for low transaction costs by making working rules simple (however complicated and strange they may seem at first sight) and easily controllable is a fundamental characteristic of FMIS, particularly in Trás-os-Montes.

Farmer-Managed Irrigation Systems as Common-Pool Resources

Most FMIS (including related water sources) are operated as a common property resource. They are neither private (depending on the 'market') nor public (controlled by the 'state'). It is surely not evident that these communal systems are functioning well, in certain policy circles it is even considered an anomaly. The central question is how a group of individuals who are in an interdependent situation can organise and govern themselves to obtain continuing joint benefits when all face temptations to free-ride, break commitments, or otherwise act opportunistically (Ostrom 1990:29). Hardin (1968) states in his influential article *'the tragedy of the commons*' that 'a degradation of the environment is to be expected whenever many individuals use a scarce resource in common'. For irrigation systems dependent on surface water sources, this means an increased competition between water users, inefficient water use, increasing difficulties to reproduce the system (lack of maintenance and repair), the usurpation of the irrigation water by some users or a group of users (e.g. the farmers at the head end of the system) and finally the breakdown of the systems. In the case of groundwater (an open-access resource) it leads to overexploitation and redistribution of water in favour of farmers with more powerful pumps. The Hardin thesis (and other related models) has been and still is very influential in academia and the world of politics. It constitutes the foundation of recommendations that the State must take control of common-pool resources (CPRs) or privatise them to prevent their destruction[12]. Ironically, state-controlled 'modern' irrigation systems suffer most under the plagues of free-riding, rent-seeking and corruption. In many cases transaction costs, i.e. the cost of creating and maintaining an agency, the costs to manage a system and the costs (lost benefits) linked to the fore-mentioned plagues are extremely high in comparison to FMIS but the theories in favour of state intervention presume that transaction costs are insignificant and can be ignored (Ostrom 1992). On the other hand nowadays there are many who argue that privatising those resources will resolve the problem. Both centralisation and privatisation advocates accept as a central tenet that institutional change must come from outside (the 'state' or the 'market') and be imposed on the individuals affected (Ostrom 1990:14). Instead of presuming that the individuals sharing a commons are inevitably caught in a trap from which they cannot escape, Ostrom (1990) starts from the empirical diversity of CPRs in an attempt to understand why some efforts to solve commons problems have failed while others have succeeded. She analysed different empirical cases in highly diverse contexts of successful efforts and failures to govern and manage such resources in order to identify the internal and external factors that can impede or enhance the capabilities of individuals to use and govern CPRs (Ostrom 1990:27). The central question is how they have created institutions, committed themselves to following the rules, and monitored their own conformance to their agreements, as well as their conformance to the rules in a CPR situation (Ostrom 1990:45).

Many FMIS are examples of successful CPRs. Ostrom (1992) called them long-enduring self-organised irrigation systems. They are in operation for at least several generations. The repeated willingness of users to operate and maintain these systems is strong evidence that individual farmers receive more benefits from these systems than the costs they assume for maintaining them (Ostrom 1992:68).

Analysing successful CPRs, in particular long-enduring, farmer-managed irrigation institutions in various settings, Ostrom offers as part of the explanation for their institutional robustness and sustainability the fact that their particular rules differ. The differences in the particular rules take into account specific attributes of the related physical systems, cultural views of the world, and economic and political relationships that exist in the setting (Ostrom 1990:89). Analysing a lot of empirical material she derived core design principles underlying the specific rules that users have developed in crafting their own irrigation institutions. A *design principle* is defined as:

> *'an element or condition that helps to account for the success of institutions in sustaining the physical works and gaining the compliance of generations of users to the rules-in-use'* (Ostrom 1992:68).

These design principles are listed in Box 1.1. They are stated in general terms. In the following chapters I will come back to these design principles that can explain the meaning of certain rules in FMIS and can serve as instruments to design new rules or adjust old rules in irrigation systems.

Understanding the nature of FMIS: The hydraulic property theorem

I am aware of the massive literature on Farmer-Managed Irrigation Systems. In this book I will not present a review[13] of this very heterogeneous literature from different scientific disciplines (anthropological, sociological, political, managerial, technical), reflecting experiences from all parts of the world. In certain parts of this book I will refer to this literature where it is appropriate. The technical irrigation literature does not refer to FMIS and their functioning very much and where it does, mostly in a derogatory manner in the sense that they do not represent efficient irrigation practices, a subject to which I will come back in Chapter 6. Farmer-managed irrigation in Portugal is a little explored subject of research[14], at least in relation to the lion's share of the FMIS in the whole irrigation sector of Portugal. For Portuguese irrigation technicians and policy circles this 'discovery' is relatively recent and somewhat surprising[15]. In this thesis I hope to make a modest contribution to a better under-standing of farmer-managed irrigation, its importance and development in the context of Portuguese agriculture.

Apart from the CPR theory of Ostrom I would like to mention another theorem that was an eye-opener to me in understanding the nature of FMIS: the concept of hydraulic property. Coward (1985) conceptualised irrigation development as a process in which people establish rights to irrigation water by investing in the creation and the continuing reproduction of physical infrastructure. In that way they create hydraulic property. 'As new objects of property are created, the relationships among people related to that object of property may also be adjusted or created *de novo*' (Coward 1985). This implies boundaries (who is entitled to irrigation water and who is not) and a relation between benefits (rights to water in the quantitative sense) and costs (to create and reproduce the hydraulic infrastructure), very similar to the first and second design principles already mentioned in Box 1.1. It will be clear that the concept of hydraulic property comes very near to the CPR theory of Ostrom from which some main points I have resumed in the foregoing. I do not pretend to criticise nor to contribute to the further development of this theory. For me, as practising irrigation engineer with a strong interest in analysing problems and contributing to their solution, it was a very useful instrument to understand the functioning of FMIS. An understanding of the hydraulic property concept and the CPR theory are basic to the design of meaningful interventions in irrigation systems in general and FMIS in particular. In my opinion, these theoretical building blocks should be incorporated in the training of irrigation engineers and professionals[16].

Box 1.1 Design principles underlying long-enduring, self-organised irrigation institutions (Ostrom 1992)

1. *Clearly Defined Boundaries*
   The boundaries of the service area and/or the individuals or households with rights to use water from an irrigation system are clearly defined.
2. *Proportional Equivalence Between Benefits and Costs*
   Rules specifying the amount of water that an irrigator is allocated are related to local conditions and to rules requiring labour, materials, and/or money inputs.
3. *Collective Choice Arrangements*

Most individuals affected by operational rules are included in the group who can modify these rules.

4. *Monitoring*
   Monitors who actively audit physical conditions and irrigator behaviour, are accountable to the users and/or are the users themselves.
5. *Graduated Sanctions*
   Irrigators who violate operational rules are likely to suffer graduated sanctions (proportional to the seriousness and context of the offence) from other irrigators, from officials accountable to these irrigators, or from both.

Up to this point Ostrom summarised her argument as follows:

> 'When users design their own operational rules (design principle 3) to be enforced by individuals who are local users or accountable to them (4) using graduated sanctions (5) that define who has rights and duties related to an irrigation system (1) and that effectively allocate the water available during different seasons of the year and other relevant local conditions (2), commitment and monitoring problems are resolved in an interrelated manner'.

6. *Conflict Resolution Mechanisms*
   Users and their officials have rapid access to low-cost, local arenas to resolve conflicts among users or between users and officials.
7. *Minimal Recognition of the Right To Organise*
   The rights of users to devise their own institutions are not challenged by external governmental authorities.

For FMIS that are parts of larger systems:

8. *Nested Enterprises*
   Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organised in multiple layers of nested enterprises. In that case different levels of irrigation operation (e.g. system level and tertiary level) are established at points where water is` divided into smaller branches.

FMIS in a changing context

In this book I will develop a detailed description of the Farmer-Managed Irrigation Systems as I came to understand them in Trás-os-Montes, especially in the part called Barroso. I will pay ample attention to the way these systems are adapted to the particularities of local conditions and consequently to the considerable heterogeneity that is manifest at the level of the area as a whole, as far as irrigation systems are concerned. I will also describe the inherent dynamics of these systems. They have not only been adapted to changes in space but also to changes in time, albeit to different degrees and in contradictory ways, as will be explained below.

Yet, right at this moment the very *continuity of FMIS* seems to be at stake. Basically this comes down to two phenomena. The first is that in the course of the centuries labour was abundantly available within the agricultural system of Trás-os-Montes and consequently, the availability of labour was hardly any restriction as far as the construction, management, maintenance and consolidation of irrigation systems were concerned. This could clearly be observed in the landscape of Trás-os-Montes which itself can be conceptualised as objectified labour. Many irrigated perimeters and other areas are constituted by man-made terraces with numerous walls and small plots. Soils in this areas are also man-made through continuing heavy organic manuring. Precisely at this point there has been a dramatic change: labour became a scarce resource, principally due to the enormous migration flux to Western Europe since the end of the 1950s (see Chapter 4). As we know from other parts in the world, once the reproduction of an agricultural system becomes endangered, a slow but steady regression at the level of production, the ecosystem and the physical infrastructure[17] is nearly unavoidable. Directly related to the shortage of labour is the low profitability of agriculture. The economic strategies of rural households and the prospects of the young generation are increasingly influenced by incomes that can be generated outside agriculture. The above-mentioned scarcity of labour, the crisis in agriculture, the opportunities and prospects outside the agricultural sector are affecting the sustainability of irrigation systems. That manifests itself in different and contradictory ways. Some FMIS have already been abandoned, others are in decay, principally those with a low hydrologic potential. Sometimes their water sources have dried up as a result of private water development, sometimes the water sources will now be used by a few people, for instance those who have plots near the source or owners of pumps. In either case, a redistribution of water will take place. In another category of FMIS, an increasing tension is developing between their functioning and the actual context of scarcity of labour. These systems, emerged and developed in a context of an abundance of labour, are increasingly disadjusted to the actual changed context. Further development of these systems is characterised more and more by stagnation and involution (Geertz 1963).

As an analytical concept Geertz defines involution as: the overdriving of an established form in such a way that it becomes rigid through an inward overelaboration of detail[18] (Geertz 1963:82). In an involutionary kind of development the basic pattern of functioning remains the same but keeps on developing by becoming internally more and more complicated. In this involutionary process of ‘changeless change’ (Geertz 1963:96) its details develop further and further. In a broader sense involution is characteristic for a development path leading to a deadlock.

Through this involutionary process of perfectioning and inward overelaboration of details the irrigation systems become rigid. This makes it more difficult to forge a qualitative transformation of the functioning of the system such that it is better adapted to or ‘in line’ with the changed context of shortage of labour. These systems seem to have reached their ultimate form, they function still but their development is a variation of the same basic pattern. They stagnate without a perspective of agrarian development; the only things that are changing are details (e.g. further division of water rights along with landed property etc). In these systems there does not seem to be sufficient internal force, as if many users are tired, think it is not worth to revitalise them, to adapt them to changed circumstances. Better not to take risks, the status quo offers at least security, you know what you have, what is the need to change?

With respect to institutional change Ostrom made a useful distinction between different layers of rules. She distinguishes operational rules, collective-choice rules and constitutional rules (Ostrom 1992:45).

Operational rules regulate the day-to-day use of the system (the processes of appropriation, provision, monitoring, enforcement). Collective choice rules determine the process of operational rule making (policy making, management, adjudication). They regulate, for instance, how the day-to-day use of a system could be adjusted to changing circumstances. These type of rules constitute the mechanism for changing operational rules. Constitutional-choice rules determine who is eligible to take part in rule-making, and the specific rules for the crafting of collective choice rules (formulation, governance, adjudication, modification).

Not all these layers of rules can easily be distinguished in most FMIS in Trás-os-Montes. Constitutional questions hardly exist. The community of water users, the limits of the system and its water source(s) are normally clearly defined. But collective choice rules hardly exist; there exist no clear mechanisms and arrangements between the users how to make and change operational rules. Water users do not have organisations at that level. The strength of FMIS is that their functioning follows a clearly crystallised pattern because their operational rules are well defined, followed, monitored and sanctioned by the users. But at the same time this could become a weakness. The actual operational rules in FMIS have been crafted and developed in the past along a certain path, following a certain logic. In the meantime, following the same development path, the rules have become highly specific and detailed. Van Steenbergen (1997:109) gives an example of local water delivery schedules in farmer-managed irrigation systems in Balochistan, Pakistan which are rigidly described and are followed nearly 'automatically', each water user knowing his entitlement from the system. In many FMIS in Trás-os-Montes the same is valid for the summer irrigation allocation and distribution. Following van Steenbergen's argument, this leads to a paradox: with an increased specificity of rules, there will be less need for a co-ordinating organisation. That implies that transaction costs are minimal. However, without an actively co-ordinating organisation, required changes in working rules will be difficult to initiate. The specificity of rules, the result of a path-dependent development (North 1990), will be a brake on change. Applied to water delivery schedules, a very rigid and specific schedule will not be easily revised; instead the schedules will be kept acceptable by 'muddling through', primarily interindividual adjustments, such as exchanges and transfers of water turns between water users (van Steenbergen 1997:110). The development of the systems becomes more and more involuted, their development path ends in a deadlock. Only if new perspectives with clear gains are possible and are actively pursued by a co-ordinating organisation the working rules can be changed and FMIS revitalised. It is an open question whether, how and where these conditions exist or could be created in Trás-os-Montes.

The second problem related to the continuity of FMIS is more or less introduced from the outside. That is that the agricultural sector of Trás-os-Montes and Barroso in particular has increasingly become the object of outside interventions aiming at an overall modernisation[19]. New farming patterns are stimulated that will require much more irrigation water, precisely in the summer period when water is most scarce. This clashes diametrically with the nature of actual irrigation practices. About the outcomes I am not too optimistic. It can be foreseen that increasing competition for scarce water resources will occur which will increasingly undermine existing FMIS. This tendency is strengthened by subsidising the development of individual irrigation facilities.

Modernisation: replacing FMIS or developing them further?

In the typical analysis underpinning modernisation programmes the locally existing agricultural systems are, in accordance with the well-known thesis of Schultz (1964), considered 'efficient but poor'. It is recognised that farmers make the best of the existing technical possibilities (as e.g. embodied in available irrigation systems). They are very close or have even reached the 'technical ceiling' as contained in the existing resources. But they are poor at the same time. The 'technical ceiling' does not allow for anything more. Hence, in the end there is just one solution, that is to *replace* the existing resources and technologies with other, more productive ones. The existing FMIS, being barriers to further development, are to be replaced by new, more efficient irrigation systems that allow for a new 'take-off' of agriculture. In this book I will give evidence of this typical Schultz-type diagnosis.

The central question of course is whether this modernisation approach, which definitely implies a rupture with existing irrigation practices, is the only way out. Is an alternative development strategy possible, that is a strategy that builds upon rather than marginalises the existing FMIS? That raises the question of the development potential of the skill-oriented irrigation technology in these systems in relation to the changed context. What are the possibilities to build upon traditional practices, developing them further and adapting them to changing conditions and perspectives? Is it possible to make meaningful changes in rules and artefacts which constitute a step forward? Could FMIS be redesigned based on their own logic of functioning?

Agrarian development and irrigation

Throughout this book I will insist on the very close interwovenness of agriculture and irrigation. This interwovenness runs deeper than the conversion of water in crop production as the core subject of the irrigation agronomy, namely crop water requirements, soil-water-plant relations, water-yield relations and field irrigation methods etc would suggest. Although these subjects are very important and important tools which I will use extensively throughout this book, I will consider irrigation, in the first place, as an integral part of farming practice.

At farm level, irrigation is both a resource and an activity. Irrigation water as a resource has specific space and time characteristics. Its availability and quality are highly variable in these dimensions, dependent on climatological and hydrological conditions. The farmer co-ordinates the use of irrigation water with the application of other farm resources (land, capital etc.) to realise certain household production goals.

Irrigation also constitutes an activity that the farmer needs to combine with the whole of farm and eventual off-farm activities. Apart from the activity of irrigating, the security, reproduction and enlargement of available irrigation water need investments for the construction and maintenance of physical infrastructure. Operating and maintaining irrigation facilities imply the development of specific social relations among water users.

Within a specific context with its limitations and opportunities, farmers purposefully integrate the use of water in their farming systems. Irrigation technology is an instrument for land use intensification and increasing labour productivity. But in every farming system there is a specific balance between these two factors. A certain type of irrigation technology will be more appropriate to a specific farming system than to another. That is to say that irrigation has a specific role in different farming systems (see also van Bentum 1995: Chapter 8), as will be shown in Chapter 5. It also means that agrarian development and irrigation development are inseparable.

Exogenous vs. endogenous development

In Trás-os-Montes and in Barroso in particular, contrasting agricultural development patterns are encountered, with different demands on water and irrigation technology. In synthesis: there are parts of agriculture that are modernising along the well-known lines of further scale-enlargement, intensification[20], specialisation, application of new technologies and further integration with agri-business. Following van der Ploeg *et al.* (see van Dijk and van der Ploeg 1995; Long and van der Ploeg 1994; van der Ploeg and Saccomandi 1995) I will refer to these trends with the concept of exogenous development. Simultaneously, in the rich diversity of Barroso agriculture several 'counter-developments' are noticeable. Farmers build on the locally available resources (the *baldios*[21], the FMIS, the local breeds, the networks linking farming with other sectors, etc.) to construct alternative development trajectories. I will refer to the latter with the concept of endogenous development, that is, development that does not imply a rupture with existing practices, but rather builds on existing resources and practices[22] (see also Cristóvão *et al.* 1994; van der Ploeg and Long 1994; van der Ploeg and van Dijk 1995). Finally there are large segments of local agriculture that follow none of the indicated routes: these segments are quickly marginalising. For them (subsistence) agriculture is in the process of becoming just one component in their livelihood strategies.

The differentiation within agriculture, which is clearly linked with differentiated irrigation practices, allowed me to make a comparative empirical study of different 'technological trajectories' (see Chapter 5). I could compare the overall effects and the resulting water-use-efficiency of the modernisation approach with the endogenous type of development. I do not want to run ahead of the details of such a comparison here. The overall impression, though, is that the current 'blueprint' approaches for modernisation[23] only deepens the marginality of the agricultural sector in Trás-os-Montes.

The possibilities for redesign of FMIS

This finding renders even more urgent the final task I set for myself, that is, to examine *how endogenous development can be strengthened by using the design capacity of* *science*. It will be understood that I do not pretend to respond such a question generally. I will focus on irrigation. Then this question comes down to the development potential of FMIS, the possibilities to adapt FMIS to a changing context and its translation into new working rules and technical irrigation design. But even then this question remains troubling. Based on my knowledge about the functioning of the irrigation systems, I will develop some alternative plans, some designs, in this thesis, but their eventual value remains to be assessed.

In my research I have been inspired by two approaches which have been developed by research groups at Wageningen University. One is the socio-technical approach of irrigation (Vincent 1997; Mollinga 1998: Chapter 2; Bolding *et al.* 2000; Artifakto '90 1990) developed since the 1980s at the Irrigation and Water Engineering group (formerly called: '*vakgroep tropische cultuurtechniek*'), the other is the farming styles approach (van der Ploeg 1990, 1991, 1994a, 1999) initiated and developed by the research group at the Rural Sociology department headed by Jan Douwe van der Ploeg. Without going into the detail with respect to these approaches I consider as the most important common focal points the search for understanding agriculture and irrigation as socio-technical practices (human activities with social and technical dimensions), the interwovenness of the social and the material (technology as the combination of knowledge and instrument) and the integration of social and technical science (interdisciplinarity).

Finally I want to make it clear that this thesis is not a deductive work. Hence, this thesis is not very much 'theory-loaded' apart from some basic notions concerning skill-oriented technology, institutions and transaction costs, endogenous vs. exogenous development, the complex interwovenness of farming and irrigation, which I have detailed a bit in this introductory chapter. It is, above all, a search for a meaningful interpretation and an endeavour to come to grips with the unruly characteristics of the *empirical reality of complex irrigation practices*. It is, therefore, an exploratory study.

Research framework

I have carried out the field work for this thesis in Trás-os-Montes during 1992-1993 in the framework of the research project 'Design Methods for Endogenous Regional Development'[24]. This project contained research aiming at the identification and strengthening of the development potential and the strengthening of endogenous development patterns in marginal areas in Europe. In Trás-os-Montes, FMIS had been identified as an important local resource and research in their functioning was obvious. In that context the subproject 'Intervention Strategies in Traditional Farmer-Managed Irrigation Systems in Northern Portugal' was implemented. This joint research was carried out by the Department of Economics and Sociology (DES) of the University of Trás-os-Montes e Alto Douro (UTAD) in Vila Real, Portugal and the Department of Irrigation and Soil and Water Conservation[25] of the Wageningen Agricultural University (WAU), the Netherlands. Many researchers, research assistants and MSc students of both institutions have been involved in the research work, providing a wealth of information on irrigation systems, the use of irrigation water, content and processes of public interventions and its effects on water availability, distribution and water use. At the same time other colleagues carried out research on the use of other local resources such as the *baldios*, the manure (E. Portela 1994; E. Portela *et al.* 1994), the commercialisation networks of local breeds (Tibério 1994) and the local knowledge systems (Izarin 1992, 1993; Koehnen *et al.* 1992; Oostindie *et al.* 1993). An integrating element was constituted by the research into local farming styles (Cristóvão *et al.* 1994; Oostindie *et al.* 1993). In Chapter 5, I build on the results of this research.

At the time of research (1991-93), FMIS were subject to interventions by the Portuguese state. The intervention program, called 'Improvement of traditional irrigation systems' (MRT[26]) was executed by the Trás-os-Montes Integrated Rural Development Project (PDRITM)[27]. The MRT programme was set up without detailed knowledge of the complex functioning of traditional irrigation schemes prior to improvement. The research project 'Intervention Strategies in Traditional Farmer-Managed Irrigation Systems in Northern Portugal' aimed at getting a clear insight into the functioning and dynamics of FMIS, the intervention process as implemented by PDRITM and the effects which are generated by the interventions. The objective of the research was to develop a typology of FMIS which could serve to identify relevant elements for designing improved intervention strategies aimed at different types of systems.

The research activities on irrigation systems included two inventory studies to identify key elements relevant for the diversity and functioning of FMIS and for intervention purposes. The first inventory study also served as a basis for the selection of case study sites to study certain aspects in depth, apart from a description of irrigation practices in their local contexts. These case studies were executed by Portuguese and Dutch students in the framework of their MSc research. This thesis draws heavily on these inventory studies[28], the various case studies[29] concerning the functioning of village irrigation systems and the findings and studies[30] of the UTAD/DES based Evaluation Unit of the PDRITM interventions.

Finally, in time and space co-ordinates this study is based on research in the Mountains and High Valleys which are the two agro-ecological zones of Trás-os-Montes in which irrigation is concentrated (see Chapter 2, Fig. 2.2). Temporally the study focuses on the period from 1980 until about 1994, coinciding roughly with the period in which Portugal entered in the then EEC and the PDRITM was prepared and executed.

Methodological aspects

Fieldwork for this thesis was carried out during 1992 and 1993. I participated in the FMIS inventory study, stayed for some periods in one village near Chaves, observed the irrigation practices in two mountain villages near Vila Real on a regular basis, I assisted MSc students in their case study research, designed and assisted in a flow measurement programme and visited many villages, irrigation systems and farmers in Trás-os-Montes, particularly in Barroso, alone or with colleges. Besides farmers I spoke to key informants such as a postman from the town of Vinhais. For some days I accompanied him on his mail delivery to various villages between Chaves and Vinhais. This turned out to be an excellent method of visiting a whole series of villages, to collect data and to get to know other key informants. For instance, in this way I met the owners and operators of two small enterprises which are making ditches and boreholes for farmers. They turned out to be very valuable informants regarding data about individual water resources development and related questions regarding the undermining of FMIS.

There have also been some contacts with technicians of the MRT program and the Regional Directorate of Agriculture (DRATM[31]) in meetings, excursions and interviews. Unfortunately I cannot ignore that these contacts were not very fruitful, the main problem being a fundamental distrust on the part of the technicians of the UTAD researchers and evaluators of the PDRITM program. The technicians simply stated that the researchers, based on the Department of Economy and Sociology of the UTAD, are incompetent to assess and eventually to contribute to the improvement of their work[32].

The research methods were simple. Basically, they amounted to walking through villages and their (irrigated) farming areas; observing and comparing what was happening in the irrigated areas; observing water sources and measuring water flows; accompanying water users when they were irrigating; offering a helping hand in some farming activities; talking to women working in the 'collective' oven; meeting people at village '*festas*'; chatting with young people in local cafes and discotheques; questioning, talking and discussing issues related to irrigation practices and agricultural development with farmers and other local key informants (e.g. teachers, priests, local politicians).

In the early stages of the fieldwork it was sometimes not that simple to find the correct tone. One episode precipitates as a clear mental image in my head. A Portuguese colleague and I entered a village where we did not know anybody. Then, in the local cafe someone, introducing himself as João Diabo ('John the Devil') asked us: 'who are you, unknown faces, and what are you here for?'. We answered that we wanted to do an investigation of the irrigation systems in the village ('*fazer uma investigação de regadios'*) but the people present immediately interpreted our words as if we were policemen. For the villagers the word '*investigação*' was strongly associated with action of the police ('*investigação criminal'*). Maybe not so strange in a village that was very near the Spanish border in which smuggling was a general practice until recent times[33]. It took some trouble to clear up this misunderstanding. One thing was sure, we immediately banned the word '*investigação*' from our vocabulary. Even after that event other people confused us with plumbers coming to repair the domestic water supply, a group of women asked us if we came to install telephones etc. Frequently, expectations existed that we could influence state services in their decisions to intervene in this or that irrigation system, explaining the contrary was sometimes laborious. On the other hand it was not difficult to find points of identification: the most important was the Portuguese language but also the fact I had worked a long time in Mozambique where many Portuguese people lived for longer or shorter periods, the references to the seed potatoes and the Friesian milk cows from the Netherlands, football etc. In general, I was deeply impressed by the willingness of people to talk with us and their overwhelming hospitality. Innumerable times they invited us to taste their home-made wine and cured ham, a great source of pride for them.

One problem was that during the research it became clear that many water users had no (detailed) overview concerning the functioning of their systems[34]. When asked they responded frequently in a vague way, saying: *'A água anda por aí, depois por aqui'* what means ‘now the water flows there, it will come here after’. Often they called or indicated key informants, mostly elderly men, to clarify certain questions.

Another associated problem was to interpret the sometimes contradictory, highly contextual and local specific information needed to understand a certain situation. Examples are the existence of different names for the same persons and objects or the same name for different things, the complexity of relationships between households, objects and the external world.

Data Analysis

To systematise the data on the functioning of the irrigation systems I used the Uphoff matrix of irrigation system activities (see Box 1.2). It turned out to be a very useful research tool.

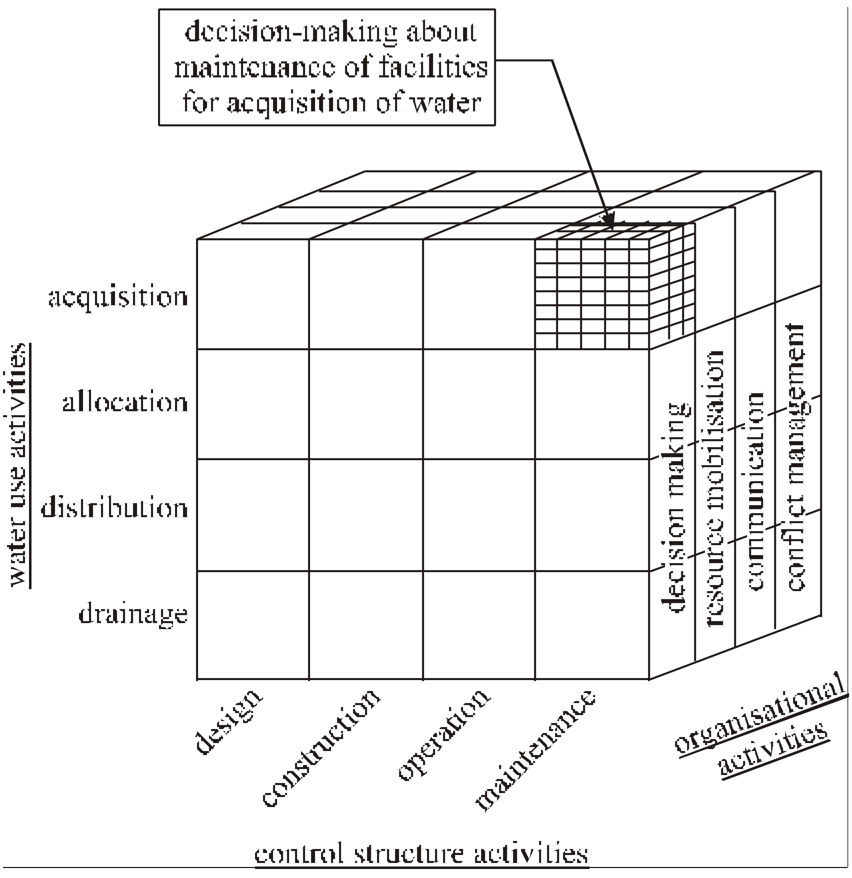
To study some specific questions I made use of two other research methodologies, namely the analysis of farm accountancy data and the results of a channel flow measurement program.

Box 1.2 The Uphoff matrix of irrigation system activities

The matrix allows to identify the possible and interrelated activities that take place in an irrigation system (see Figure below). One set of activities focuses directly on water. Water must be acquired, allocated, distributed, and if there is an excess, drained. A second set of management activities deals with the physical structures for controlling the water. A final set of activities is related to the social organisation of irrigation, focussing on decision-making, resource mobilisation, communication and conflict management. Each of the 64 boxes is potentially an interaction. For example, one might ask what decisions need to be made about the operation of the system as it relates to water distribution.

In each specific context some activities are crucial while others are less relevant. For instance, drainage in many FMIS is of minor importance in the mountainous conditions of Trás-os-Montes. In this thesis I will focus on the allocation and distribution of water (water use activities) and the design and operation of the system (physical system activities), which are the most relevant activities in the functioning and improvement of the systems.

Irrigation management activities in three dimensions



Source: Uphoff *et al.* (1991:54)

A basic assumption of the PDRITM programme has been the inefficient use of land resources and irrigation water in traditional agriculture. In that context, PDRITM has stimulated and supported the development of exogenous farming patterns in which the role of irrigation and the requirements of irrigation water is fundamentally different. To compare and analyse the different water requirements of those opposed farming systems, I used farm accountancy data from a group of farms in Barroso. The results of this comparison are shown in Chapter 5.

The PDRITM interventions in FMIS have been justified on the basis of the assumption that heavy infiltration losses occur in the unlined irrigation channels but this assumption had not been empirically tested. To determine real flows and real water losses in the irrigation channels I assisted in the design of a flow measurement programme. In Chapter 6 the main results will be discussed.

Throughout this book I shall use the computer program CROPWAT[35], a simple program based on plant-water-soil-atmosphere relationships to simulate the variation of soil moisture in the root zone during the growth season and to estimate yield reductions. This allowed me to analyse, to illustrate and principally to compare the productive effects of various management options in typical FMIS conditions.

Organisation of the book

Some chapters of this book elaborate on previous published articles and case studies performed by students as part of their MSc research work[36].

Chapter 2 is basic to an understanding of the skill-oriented technology entailed in the functioning of FMIS in Trás-os-Montes. It describes and analyses farmer-managed irrigation in Trás-os-Montes, the principles which underlie its functioning and its characteristics, in particular its complexity and dynamics. I will first give a description of the context in which FMIS operate, the relevant characteristics of farming systems, irrigated agriculture and common features of irrigation systems. Then I will deal with the key elements that are strategic to the functioning of the irrigation systems and determine its diversity. Finally, the dynamics and stagnation in farmer-managed irrigation will be described and discussed.

In Chapter 3, I will illustrate the skill-oriented nature and complex functioning of these systems by presenting two case studies of farmer-managed irrigation systems, respectively in the villages of Romainho and Vila Cova. The last case study serves as the basis for the formulation of an alternative improvement plan for the system, presented in Chapter 7.

Chapter 4 presents an overview of the socio-economic conditions of Trás-os-Montes, changes that have occurred since the last decades, the analysis of these conditions and problems by the State institutions and the responses and development interventions of the State – based on this analysis – resulting in the introduction and development of exogenous farming patterns

In Chapter 5, I will analyse the irrigation demands of the exogenous agrarian pattern and compare those with the endogenous agrarian pattern. I will deal with related questions such as the development possibilities of the exogenous farming pattern and the possible consequences and implications of this development.

Chapter 6 presents a critical analysis of the irrigation interventions, particularly the MRT intervention. In particular, I will deal with the underlying assumptions, effects and relevance of the MRT intervention.

Finally, in Chapter 7, I will present some ideas and approaches to improve irrigation interventions and to redesign FMIS. First, I will discuss the potential impact of contrasting farming development patterns on resource use and policy implications. Second, I will formulate some alternative intervention strategies with the potential to improve actual irrigation interventions. Finally, I will deal with the question of the development potential of FMIS and its translation in combinations of technical and institutional design aimed at adapting the systems to the new context of rural society in Trás-os-Montes. I will focus on the aspect of labour scarcity, that is to say, how irrigation practices could be adapted to this constraint.

Notes

1 What at first sight could appear an insignificant and silly detail, for instance the size of a seed, could be crucial. To illustrate this I refer to an example from Nicaragua. I visited two co-operatives in the district of Chinandega which, in the framework of an export-stimulating program, cultivated sesame for the first time in the dry season with sprinkler irrigation. An agricultural extension service assisted them with technical advice. The technical advisors recommended applying an irrigation turn directly after sowing. One co-operative followed that advice but their crop did not germinate because the very small sesame seeds were washed away into deeper soil layers. The other co-operative did not follow the advice, they applied a light pre-irrigation before sowing and only irrigated 3 weeks after sowing when the crop had already germinated and established well.

2 But the design and production of a central pivot requires highly specialised education and skills.

3 This condition is crucial but sometimes overlooked, as I will illustrate with some examples from Nicaragua. After the Sandinistas took the power in 1979 they gave a high priority to the development of agriculture at the service of small farmers (*campesinos*) and urban poor classes. But for the Ministry of Agriculture this meant in the first place the ‘modernisation’ of agriculture in the ‘American’ way. Irrigation was seen as a basic tool for that. It was planned to irrigate the whole Western part (the Pacific plain) of the country with thousands of central pivots. Dozens of pivots, each irrigating about a hundred hectares, were installed at the newly created sugar estate ‘Julio Buitrago’. In this area with a great heterogeneity of soils ranging from loamy sands to heavy clays, the latter used until then mainly for rice production, the operation of the central pivots proved very problematic. When operating on heavy clay soils, the wheels supporting the pivot beam got stuck in the mud right from the start, the result of the high intensity rain produced by itself. When a central pivot was installed on different soils, for instance one part in clayey soil, another part in sandy soil, another problem arose: the wheels running on sandy soil met with less resistance, hence wanted to go faster than the wheels driving on clayey soil. This resulted in enormous tensions and distortions in the pivot beam and consequently very high repair costs. After many experiments with all type of wheels, it was concluded that there was no solution in that direction and the technician conducting the trials was fired. In the end a very expensive solution was implemented: constructing a circular road paved with stone and concrete for every wheel. Ironically, after some years the technician who conducted the trials with the wheels announced that he

had discovered the definitive ‘wheel solution’, but then the financial resources lacked to put this solution to the test.

Also some big pivots have been installed in co-operatives and small farmers communities. As could be foreseen, the pivots whose operation pre-supposes uniform mono-cultures, proved completely incompatible with the local way of farming and the local cropping system characterised by small or medium sized plots of different crops with different sowing times and crop rotations.

4 These terms refer to unfolding possibilities and principles abstracting from the specificity of time and place. On the contrary, a farming style is a time and space dependent expression of a more general style of farming (see van der Ploeg 1999:154)

5 An intriguing question in this area, considered as a model agricultural area with the best production conditions in the Netherlands, concerns the different opinions and practices of farmers related to the use of sprinkler irrigation. I became interested in this question when I was working on my father’s farm during the summer of 1976. Before the dry summer of 1976 sprinkler irrigation of field crops (most important crop: potatoes) hardly took place. Traditional sprinkler irrigation techniques (hand-move systems) were not an option because they required too much labour. Approximately in the mid -1970s, a new labour saving technique became commercially available: the continuous-move raingun traveller coupled to a pump operated by the power take-off of a tractor. In 1976, farmers invested massively in this type of sprinkler equipment. In that summer many problems occurred, principally burnt tractor engines because of sudden pressure loss (by tubes that broke down), even rumours spread about completely burnt-out tractors because the water of the raingun had made contact with high voltage electricity supply lines etc. After these experiences the sprinkler manufacture industry perfected the technology, e.g. with safety devices on tractors against sudden lowering of water pressure etc. But even then an intriguing question remained: one group of farmers made sprinkler irrigation (and its frequent use) one of the fundamentals of their way of farming while their neighbours -in the same ecological circumstances, the same crops and soils- did not apply this technique, or only in exceptional circumstances. Advocates of sprinkler irrigation mention the higher yields but their opponents mention such arguments as that irrigation makes the plant roots lazy (my father remarked ‘*je moet ze de grond in pesten*’ which means ‘you have to pester them into the soil’) which on its turn increases still more the dependency of crop growth on irrigation. At the other hand such an expensive investment can only be made profitable when it is used frequently. The adversaries also mention reasons of labour input and psychological reasons (‘I cannot sleep when I think what can happen, if the raingun topples over for one or other reason, for example a local gust of wind, then the following morning I will be confronted with a big gully or hole in my land’).

6 A Portuguese official remarked: ‘The only time there is a murder in Trás-os-Montes you can be sure it is over water. There’s no crime. You can leave your house unlocked. But the prisons are filled with men who have committed crimes over water’ (McGirk 1989). Besides the economic value of water, Wateau (2000) pointed at the symbolic dimension of the conflicts regarding this resource, that is to say many conflicts are not about water but water serves as a pretext for battling out other contradictions at the local level or between households.

7 Ferreira (1991:39) tells how this old rule was used by people of the hamlet of Corva to substract water from a brook which was already in use by the hamlet of Paredes. Just in time someone from Paredes came to stop them from completing the canal which was diverting the water from the brook. Anyhow the resulting conflict was brought to court. The judge decided to allocate to each hamlet a share of the flow. Davidse (1991) tells a similar story about the digging of a canal in the hamlet of Pereira. This affected an already existent irrigation system and gave birth to a very complex and conflictive interaction between two irrigation systems continuing till now. Also Pinto (1983) mentions a similar case in a parish in the region of Entre-Douro-e-Minho. It is remarkable that this type of rule also appears in completely different contexts. For instance, Thomas Rosenboom (1999) recounts in his

historical roman *Publieke Werken* ('Public Works') the history of a family of poor peat diggers (*veenarbeiders*) in the province of Drente (the Netherlands) who gained access to a plot by building their hut in one night and lighting their oven before sunrise.

8 In common language institutions are synonyms of organisations. In terms of the definition of Ostrom, institutions correspond to the rules of the game while organisations correspond to the players.

9 Operational rules can be divided in two broad categories. Appropriation rules regulate the allocation and use of water; provision rules refer to the construction and reproduction of the irrigation system.

10 Breaking the rules can be very profitable for the individual, for instance, when a farmer steals water to save a wilting crop.

11 This shows also the relevance of design principle 8, which deals with the organisation in multiple layers of nested enterprises, mentioned in Box 1.1.

12 Often with outcomes which are exactly opposed to the official objectives aimed for. An example is from Nepal where the government nationalised the Himalayan forests in 1957. Villagers deprived of what had been their common property began ransacking the hills recklessly, terrible deforestation was evident by the early 1970s and in 1976 the government finally reviewed the law to revive local common property institutions (McKean 1992).

13 For a nice review of past research and an agenda for future research, see Coward and Levine (1989).

14 The most important studies and research concerning Portuguese FMIS are listed in the references. In my opinion, rich fields of research are the history of FMIS and the development patterns of FMIS in relation to changing contexts.

15 M. Ramos, a former director of the department of irrigation and drainage of the DGHEA (*Direcção Geral de Hidráulica e Engenharia Agrícola*) expressed his surprise in the following terms*: in reality we are staying with an idea maybe different from the 'weight' of the traditional and collective irrigation systems in our country because it is said to us that 'they occupy approximately 580,000 ha and represent approximately 88% of the total irrigated area of Portugal continental'*(Ramos 1990:3).

16 As far as I know this is seldom the case in most training curricula of irrigation engineers world wide. In this respect, the training of students at the Irrigation and Water Engineering group of the Wageningen Agricultural University forms a notable exception.

17 Particularly, in Trás-os-Montes the rural population is indispensable for the reproduction of the landscape, the maintenance of terraces, fields and meadows, the control of erosion and the prevention of forest fires, to name only a few phenomena threatening the ecosystem. The same can be said of the local infrastructure. Until about the 1970s the State hardly invested in the rural areas of Trás-os-Montes. It has mainly been the communities performing unpaid work that created and maintained the local infrastructure as rural roads, bridges etc., in this way contributing to the improvement of Portugal's infrastructure.

18 Geertz used the concept of involution to characterise the agricultural development of Java during the colonial period till about the 1960s. He attributed to the wet-rice cultivation in a *sawah* ecosystem an extraordinary ability to maintain levels of marginal labour productivity by always managing to work one more person in without a serious fall in per-capita income (Geertz 1963:80). He saw Western intrusion as contributing to rapid population growth, and the imposition of taxes payable in sugar cane for the Dutch factories as reasons for further intensifying the use of irrigated land and rural labour. Geertz concluded that the increase in total crop output per hectare is not accompanied by a higher labour productivity and higher per capita income, constituting real development (Netting 1993:287).

19 However it is doubtful whether this intended modernisation will succeed, as I will explain in Chapter 4 and 5.

20 In the context of modernisation, intensification, that is increasing the production per object of labour (e.g. a cow, one hectare of arable land etc) is based principally on new technological means (technology dependent) such as new cattle breeds, new crop varieties, concentrate feed, fertiliser etc. Intensification can also be based on increasing the quantity and quality of labour (labour dependent). Irrigation is also a means of intensification but it depends on the type of irrigation technology whether this goes or not with a higher labour input.

21 *Baldios* are originally communal moorlands. Nearly each village in Trás-os-Montes possesses these common lands. Principally in Barroso extensive areas of *baldios* exist. They are an crucial resource in most local farming systems. The most important agricultural uses of the baldios are pasturing of cattle and the preparation of organic manure. Since the 1950s large parts of the commons have been planted with forests.

22 Christóvão *et al.* (1994:52) refined the concepts of endogenous and exogenous development. From an analysis of the heterogeneity of farming in Barroso they concluded that the concepts of exogenous and endogenous development cannot be defined by using opposing ideal types, where one is founded mainly or exclusively on 'external' elements and the other exclusively on 'internal' elements. They have only meaning as relational concepts in a certain context. Development always entail an articulation of both 'internal' and 'external' elements. Starting from this consideration endogenous development may be defined as a preponderance of internal, or local elements, which combined into a coherent model, constitutes the point of departure for the interpretation, evaluation and selection of those external elements to be integrated, so as to enhance, consolidate and/or to strengthen the set of internal elements. In exogenous development it is the other way around. It is the introduced set of external elements or a specific technological model that is used as the starting point for a reconsideration of the available local (or 'endogenous') resources.

23 It must be noted that these modernisation efforts involve a lot of public funds. It can be questioned if they could not have been spent more efficiently.

24 This research project was part of the 'Competitiveness of Agriculture and Management of Agricultural Resources' (CAMAR) programme funded by the European Community. This research project was co-ordinated by the Circle for Rural European Studies (CERES) at Wageningen, The Netherlands. In the research collaborated the 'Universidade de Trás-os-Montes e Alto Douro' (UTAD) in Vila Real, Portugal; the 'Centro per il Sviluppo Agricole e Rurale' (CESAR) in Assisi, Italy; the 'Instituto de Sociologia y Estudios Campesinos' (ISEC) in Cordoba, Spain; The Mediterranean Agronomic Institute of Chania (MAICH), Greece and the Wageningen Agricultural University (WAU) in the Netherlands.

25 Since the late 1990s split up into two chair groups: the Irrigation and Water Engineering (IWE) group and the Soil and Water Conservation (SWC) group.

26 MRT: *Melhoria de Regadios Tradicionais*.

27 The Trás-os-Montes Integrated Rural Development Project (PDRITM) launched by the Government in 1982 defined the improvement of FMIS as a basic condition for agricultural development.

28 Bleumink and Kuik 1992; Malta *et al.* 1993

29 Davidse 1991; Ferreira 1991; Morgado 1993; Strijker 1992; Stam 1993; Boelee 1992; Schultink 1992; Carvalho 1994; Pinto Marques 1994; Peixoto dos Santos 1995 ; Middelhof 1993; Prins 1991; Verstrate 1992.

30 Portela , Ribeiro and Baptista (1985); Portela, Melo and Baptista (1987); Portela (1987); Portela (1990); Portela and Baptista (1985a).

31 DRATM: *Direcção Regional de Agricultura de Trás-os-Montes*.

32 In a meeting a technician remarked: ‘our mission is to put more water into the canals and not to evaluate what people do with it, at the other hand the evaluation commission is not competent to evaluate or criticise our work but has to limit itself to the study of the effects of the improvements’.

33 O’Neill (1987:17) described a similar experience in another hamlet in the same region. When he started to do his anthropological research in that hamlet, he was suspected not merely of being a suspicious student, a government spy, a land surveyor, a professional smuggler, but also a cattle thief. That was because he spoke Galician on the first day he entered in the hamlet. That same day, two cows had been stolen from the household of the priest’s brother, and the entire hamlet suspected that Galicians had taken them across the border.

34 In his article ‘The system nobody knows’, Netting (1974) describes a similar experience in a system of a village in Switzerland. In the system he describes no one knows, even in outline the entire pattern of water distribution but each individual knows when and where he is entitled to water.

35 CROPWAT is maybe the best known irrigation scheduling programme on an international scale. The programme is based on the FAO methodology to operationalise soil-water-plant relationships (FAO 1977; 1979; 1992). The program has some inconsistencies principally in the prevision of yield reductions (van den Dries 1994a:9-12) and therefore needs to be used critically. The program is particularly useful to compare different options and situations.

36 Chapter 2 is a further elaboration of: Dries, A. van den and Portela, J. (1994), *Revitalisation of Farmer Managed Irrigation Systems in Trás-os-Montes*. In: Born from within (Eds. J.D. van der Ploeg and A. Long), van Gorcum, Assen, The Netherlands; and Dries, A. van den, Hoogendam P. and Portela J. (1996), *Effects of a technical intervention programme on water distribution and water use*. In: Crops, people and irrigation; water allocation practices of farmers and engineers (Eds. G. Diemer and F. Huibers).

Chapter 3.1 draws heavily on a case study of the irrigation system of Romainho made by Eline Boelee (1992).

Chapter 3.2 is based on: Hoogendam, P.; van den Dries, A.; Portela, J.; Stam, M. and Carvalho, J. (1996), *From allocation to distribution; operational rules in a communal irrigation system in Northern Portugal.* In: Crops, People and Irrigation (Eds. G. Diemer and F. Huibers).

Chapter 5 is a further elaboration of: A. van den Dries and J. Portela (1995), *Irrigation in two contrasting agrarian development patterns in the northern Portuguese mountains.* In: Beyond Modernization, the Impact of endogenous rural development. (Eds. J.D. van der Ploeg and G. van Dijk) Van Gorcum, Assen, The Netherlands.

Foto

2 Farmer-Managed Irrigation in Trás-os-Montes

2.1 Introduction

Irrigation development in Portugal has followed two very distinct patterns. One pattern centres around large-scale farmers. It has been and still is the focus of state policy and public investment. It is characterised by an ecological bias in favour of river plains with uniform natural conditions as well as a geographical bias mainly since the 1930s, toward the southern part of the country. Until the 1980s about 83,000 ha was developed by State intervention corresponding to 13 per cent of the total irrigated area of continental Portugal (Freund 1992). The contrasting pattern arose from smallholders' activities: in the course of the centuries they developed their irrigation facilities to serve innumerable small scattered areas, often in mountainous areas with harsh physical conditions and only marginal suitability for agriculture. These traditional Farmer-Managed Irrigation Systems (FMIS[1]) served in 1979 an area of 550,000 ha or 83 per cent of the total irrigated area in continental Portugal according to the *Direcção Geral dos Recursos e Aproveitamentos Hidráulicos* (DGRAH 1987). They are not concentrated in dry regions but distributed within regions with higher precipitation. In these regions irrigation is complementary for food crops in the summer months and to water meadows for frost protection and hay making in the other months. Small to very small family farms (<10 ha) are the prevailing production units using the FMIS, mainly in the northern and central parts where the majority of the farming population of the country lives[2]. First of all I will give a general overview of irrigation development in Portugal.

Irrigation development in Portugal

Precipitation in continental Portugal is very irregularly distributed over time and space. Rainfall is concentrated in the period from November to April. Moreover, interannual variation is large. The spatial distribution of rainfall can be described by three vectors: rainfall is decreasing from North to South, from West (littoral) to East (interior) and from mountainous zones to plains. The sharpest difference is between the mountainous and rainy Northwest and the dry low plains in the South. Policy makers and technicians call this the 'paradox' of the Portuguese territory (Castro Caldas 1991): it states that the possibilities to increase the irrigated area in Portugal are limited since land suitable for irrigation is scarce and dispersed in the regions that are rich in water resources (mountainous small holders areas in the North) while those are scarce where suitable lands abound (large-scale farms located in the Southern plains). It was argued that in these latter areas the State has to concentrate its investments in irrigation development.

The relative abundance or scarcity of rainfall and water resources is clearly reflected in the spatial distribution of irrigated areas over continental Portugal (see Table 2.1 and Figure 2.1)

Table 2.1 Distribution of irrigated areas over continental Portugal

Regions	*Irrigated areas*			
	Total (10^3 ha)	*%*	*% of cultivated farm land (SAU)*	*Most important irrigated crops*
North and Centre Litoral				
- Entre-Douro-e-Minho	160	26.8	87.8	Maize, vegetables
- Beira Litoral	110.3	18.5	48.8	Maize, vegetables
North and Centre Interior			20.7	
- Trás-os-Montes	52.9	8.9		Fodder, potato, maize
- Beira Interior	75.7	12.7		Fodder, potato, maize
Lisboa and Tejo Valley				
- Ribatejo e Oeste	110.3	18.5	21.2	Vegetables, maize
South				
- Alentejo	68.7	11.5	4.2	Rice, vegetables, fruits
- Algarve	19.4	3.2	15.1	Fruits, vegetables
Total	597.3	100	18.0	

Source: Avillez (1988), estimations based on the RAC 79 (INE 1982)

Notes:

- Statistical data from various sources differ considerably and are contradictory. One source of confusion is the difference between actual irrigated area and irrigable area, and the way these concepts are defined. Sometimes this is not clear. Another confusion is the inclusion or exclusion of the island of Madeira in the national statistics. According to the World Bank (1978:192) some 700,000 ha, or 14 per cent of Portugal's 5 million ha of crop land, are irrigated. Of this area, 90 per cent consists of 'traditional' irrigation from streams and wells by small systems constructed by farmers over the centuries. Irrigation is particularly important on small farms of the 9 Northern districts where 75 per cent of the farms and as much as 51 per cent of their land is irrigated by traditional means. Cavaco *et al.* (1998) mention a total irrigated area of 720,000 ha in 1975 and 900,000 ha in 1994, the expansion of the last decades taking place principally in Ribatejo e Oeste, Alentejo and Algarve. Pereira *et al.* (1982) mention a total irrigated area of 777,000 ha and Dias *et al.* (1986) an area of 900,000 ha for the whole of Portugal (Madeira included). Finally, IFADAP (1994) mentions an irrigated and an irrigable area of respectively 561,000 ha and 827,000 ha on the national scale for 1993.
- According to statistical data, irrigated areas diminished between 1968 and 1979 by 7 per cent although in the category of small farms (less than 4 ha) the irrigated area increased by about 15 per cent (Avillez 1984). Larcher Graça (1998) states that the total irrigated area remained practically constant, from 620,000 ha in 1950 to 626,000 ha at the end of the 1980s, but that these values obscure considerable changes at the regional scale. According to the same sources, irrigated areas have diminished 20 per cent and passed to rainfed cultivation in the interior regions of the North, Centre and South, explained as the combined result of the processes of urbanisation, emigration and afforestation. At least for Trás-os-Montes, I think this reduction is very doubtful. There, the marginalisation, abandonment of farm land and extensification of land use is combined with a concentration of farming on irrigable land. Within many farms the relative importance of irrigated plots has increased because they yield the highest and most reliable production given the limited amount of available farm labour.

Figure 2.1 Regional division of continental Portugal

History of irrigation development

According to Castro Caldas (1980), hydraulic technology was introduced by the Romans and later further developed by the Arabs, but it was principally the introduction of maize in the 16th century (and later on of potato and rice) which transformed agriculture. In the 17th and 18th centuries, mainly small farmers expanded the irrigated area by 500,000 ha, principally in the northern and central litoral parts of Portugal. The 'maize revolution' signified an enormous intensification of land use accompanied by the construction of terraces, irrigation canals and a heavy fertilisation of soils. About the history of irrigation development in the interior parts of the country little is known. Irrigation of flax has a long history and production was maintained until the 20th century. From the Middle Ages onwards irrigation of pastures became important (Wateau 2000). The two main irrigated summer crops maize and potatoes have been introduced in Trás-os-Montes in the transition period between the 18th and the 19th century (Mendes 1980; Lima Santos 1992).

In the 20th century the idea that the agrarian problem is a problem of irrigation, that 'the better use of water is the foundation of the Portuguese agriculture' (Cavaco *et al*. 1998:70) became wide-spread in circles of policymakers and technicians. This idea of irrigation as a *panacea* became and still is a constant in Portuguese politics. The water is claimed to be the only factor to solve all kinds of problems: national agricultural production, sectoral problems of agrarian development, restructuration of farm holding structure (land consolidation), regional problems of depopulation, social problems of seasonal unemployment etc. (Cavaco *et al*. 1998; Oliveira 1986).

Against this background the Portuguese State presented a plan in 1938 to irrigate 106,000 ha. One of the specific ideas of this plan, inspired by the internal colonisation in Fascist Italy (Larcher Graça 1998) was to resolve problems of access of landless and small farmers to irrigated land through the action of the created internal colonisation service (JCI: *Junta de Colonização Interna*) but the respective law had a built-in failure to expropriate land of (absent) *latifundiários*. Later on, in 1958 the Alentejo plan (*Plano de Rega de Alentejo*) was presented which foresaw the irrigation of an additional 173,000 ha. In the 1960s, agricultural politics have been oriented at the technocratic model of the 'the viable agricultural enterprise' which pointed to highly capitalised farms with economies of scale and using intensively industrial inputs. The small farmers, the '*patológicos*' (Larcher Graça 1998) were condemned to disappear.

Until 1974, on about 76,000 ha, less than a third of the planned area irrigation infrastructure had been constructed by the State, distributed over 19 systems mainly in the South. 80 per cent of this area was property of large and very large landowners (Larcher Graça 1998) practising an extensive, rainfed agriculture. No tradition of irrigation existed in these schemes. From 1974 to 1992 an additional 7800 ha had been equipped with irrigation infrastructure, 3000 ha of which in Trás-os-Montes (mainly in the agro-ecological zone of the 'Terra Quente', see Box 2.1).

State action in irrigation development focussed on the creation of hydraulic infrastucture in large-scale schemes through the Ministry of Public Works. In parallel, the agronomists and the economists of the school of the 'viable enterprise' foresaw the cultivation of irrigated fodder crops on intensive dairying farms, ignoring the production and economic logic of the farms which would benefit from the irrigation water (Larcher Graça 1998). The *essence of irrigation systems created and managed by farmer communities* had always been the strong interrelationships, or more precisely, the inseparability of water, land, crops, fertilisation and suitable agronomic practices, irrigation technology, human labour and collective action. By contrast, the drama of the 'public hydraulic works' – products of the hydro-agricultural policies of the state and the use of public funds – consists exactly in the lack of these relations between the hydraulic infrastructure, the irrigable area, the human, institutional and social dimensions indispensable to transforming the 'dry' into the 'wet' (Castro Caldas 1991). Irrigation was considered in the first place to consist of 'dams and canals' without considering farmers' needs, resources and experience in the area to be served, the suitability of lands for irrigation (Oliveira 1986) etc. The planned irrigation technology is oriented at labour saving but not always the reduction of other costs such as energy (Portela 1991a:10).

Performance of State-created irrigation systems

It is not surprising that these irrigation systems created by the State performed badly. They have never been utilised to their expected potential; only a small part (in one scheme of 12,000 ha only 12 per cent) of the potentially irrigable land is in fact irrigated (Portela 1991a). Large estates are often underutilised by their owners, who are absent or lack an interest in agriculture (World Bank 1978). Frequently, they leased out their lands on short time contracts to other farmers. The planned fodder crops to be irrigated were substituted for others demanding more water e.g. rice and tomato, not mitigating seasonal employment. In other systems an intensification of land use and farming was not possible for lack of labour and population. Desorganised urbanisation affected various irrigation systems in some places. Often only the main infrastructure has been constructed but complementary investments in drains, feeder roads and electrification were not made. Infrastructure was not completed principally at the tertiary and farm level, which was envisaged to be carried out by the farmers. There was no credit for on-farm investments like land levelling, purchase of equipment (sprinkler, trickle) etc. In the supply of water to the public irrigation systems the collected water fees cover only 10 per cent of the total management (O&M) costs (INAG 2001). Maintenance was frequently neglected for lack of funds. Irrigation systems wore out without having realised their potential. Still new irrigation areas are equipped in the same public perimeters which are only used to 60 per cent of their equipped areas (INAG 2001). The social organisation of irrigators and the creation of workable institutions have been systematically neglected. Systems are loosely managed by State-imposed Water Users Associations dominated by big landowners and technicians representing the State (Portela 1991).

The short intermezzo of the *Reforma Agrária*, product of the Carnation Revolution in 1974 had a very limited direct impact on the development of Portuguese agriculture. It is with the entry of Portugal into the EEC in 1986 that an enormous increase of financial resources became available to 'modernise' Portuguese agriculture, aimed in the first place at the creation of 'viable' farm enterprises. Irrigation development was again considered a fundamental means to this end. The Specific Programme for the Development of Portuguese agriculture (PEDAP: *Programa Específco de*

Desenvolvimento de Agricultura Portuguesa) contains various irrigation development components: the construction and rehabilitation of medium-scale irrigation perimeters, investment subsidies to the creation of irrigation facilities and the purchase of irrigation equipment for individual farmers and the improvement of traditional irrigation systems (FMIS). It has to be noted that until the mid-1980s, national agricultural politics had ignored these systems and their potentials.

The Alqueva Scheme

Currently the government still focuses on the creation of large-scale irrigation systems. The last and the largest of Portugal is the Alqueva scheme in the Alentejo region planned to irrigate 110,000 hectares from a huge dam and reservoir (the largest in Europe) constructed in the Guadiana river. After various starts and suspensions since 1976, this project was finally implemented from 1996 with an important financial contribution from the European Union. Apart from irrigation, energy generation and the creation of a strategic water reserve seem important reasons for the Portuguese government to insist in the construction of this dam (Castro Guerra 2002).

This water system and associated works have been and are strongly contested by various groups in the Portuguese society. Arguments are of different orders. Farmers' organisations proposed an alternative in the form of a series of smaller schemes spread over a larger area. Ecological reasons comprise doubts over the quantity and quality of water (the Rio Guadiana is already intensively used in Spain), the dangers of eutrophication of the lake, the salinisation and pollution of soils and groundwater aquifers as a consequence of intensive agriculture based on high use of fertilisers and pesticides (Ribeiro 2002). Economically, serious doubts exist over economic returns, a cost price of 0.13 Euro/m^3 is calculated but the government will charge 0.05 Euro/m^3 (Ribeiro 2002), the difference has to be paid from public funds. It is not at all clear which 'new' crops could be cultivated to valorise this investment and compete on the European market characterised by overproduction and on the world market. One idea is the extension of the sugar beet area, but this could be at the cost of other farming zones because sugar has production quotas (Ribeiro 2002). An important problem for agricultural intensification is the lack of labour as a consequence of the depopulation of the Alentejo region.

From a social viewpoint there are fears that the 'wrong people' will profit from this investment. There are indications that considerable speculation is taking place, e.g. Spanish agro-industrial enterprises are buying considerable tracts of land, golf fields have the first priority in water access etc.

Contradictions in national irrigation development

In the broader context of the construction of the Alqueve dam highly remarkable contradictions in irrigation development have appeared. This is for instance reflected in the abandoning of irrigation in places where it is already centuries old and the construction of irrigation where it is unknown.

Wateau (2000) gives a telling example which is worth to summarise here. He describes a part of the *Região dos Vinhos Verdes* in the densily populated district of Minho. The farming system is characterised by small-scale polyculture farming and by dual-purpose cattle breeding (milk and meat). Irrigation is a centuries-old basic farming practice. Water comes from abundant mountain sources (the mountains are called ‘castles of water’) and directed by long canals to the valleys. Agriculture is practiced very intensively on (very) small plots. These are surrounded by grapevines trained on high *ramadas* (arbors) to free the ground below them for another crop (local farmers say that their fields have two floors). These grapevines produce a typical, high quality wine (*vinho verde*: lit. green wine) with good export possibilities. Recently the Portuguese government, with financial support from the EU, has been stimulating the production of this wine but this is accompanied with a complete reorganisation of the existing farming system and the traditional way of production of this wine. Farmers are envisaged to extract the grapevines bordering the plots and to plant the whole plot with an improved variety of grapevines in monoculture. This whole operation is heavily subsidised and the economic interest of this new type of commercial cultivation have led farmers to embark on a massive restructuration of the major part of their cultivated plots. Irrigation is becoming a superfluous practice, however, because it is forbidden to irrigate these grapevines. Contrary to this paradoxal development in this area with the *savoir-faire* of irrigation and the resources in place, the Portuguese State with financial support from the European Union constructs a dam to irrigate 110,000 ha of crops in the thinly populated, dry Alentejo. It is yet more paradoxical because the *savoir-faire* relative to irrigation is unknown to the farmers, the soils to irrigate are not very suitable and the projects for irrigation development are not well elaborated.

This example shows clearly that the agricultural development policy of the Portuguese state is not based on the development of local resources. The apparent paradox could be explained if it is assumed that the agricultural policy of the Portuguese State has become focussed on the optimisation of the subsidies[3], premiums and contributions in the framework of the EU.

Irrigation Development in Trás-os-Montes

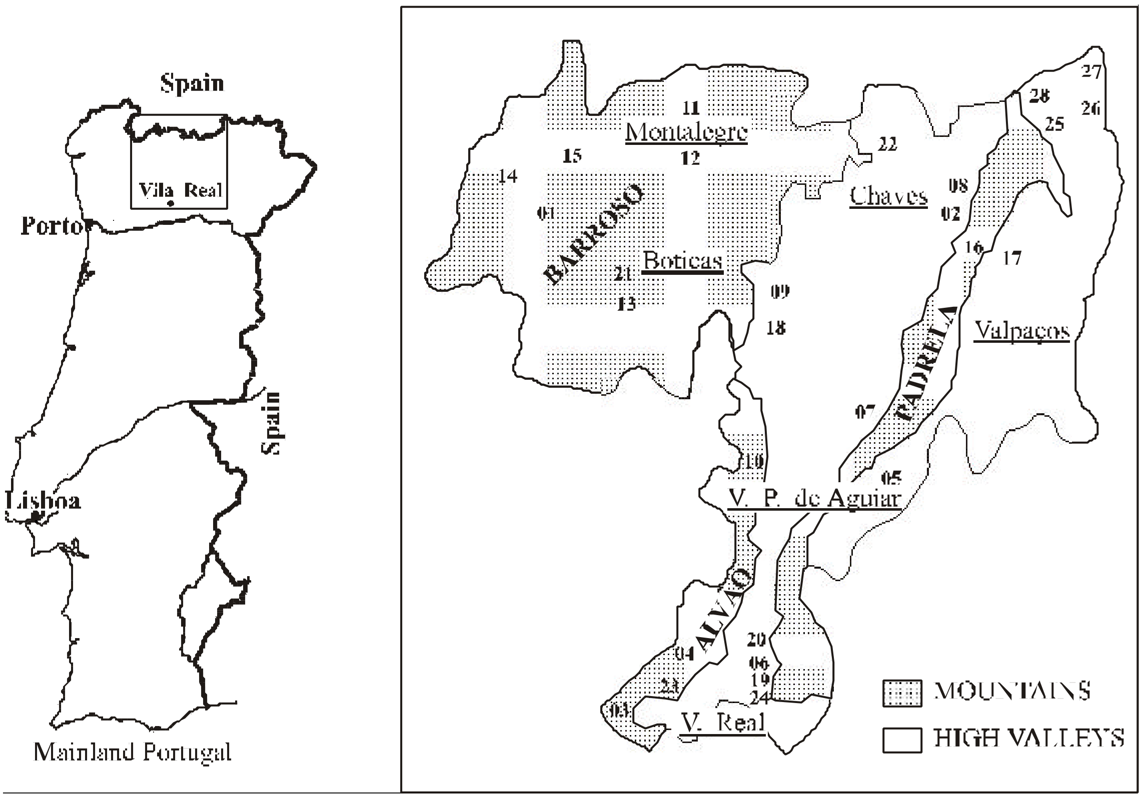
In Trás-os-Montes (literally ‘Behind the Mountains’), situated in Northern Portugal, irrigation has always played a crucial role in agricultural production[4]. Since ancient times the local populations have constructed (small) irrigation schemes within their villages which are still managed by local water users.

A 1979/80 water resources inventory in Trás-os-Montes (DGEA 1980) revealed that a large number of streams, springs and wells are used for irrigation all over the region. Excluding the hot climate central area (*Terra Quente* or ‘hot land’), more than 1000 irrigation systems[5] were identified, serving an estimated 40,000 ha. The schemes are small (the irrigated area per scheme varies between 3 and 82 ha) and concentrated in two agro-ecological zones: the Mountains and the High Valleys (see Figure 2.2). In these zones 34,000 ha are irrigated at 19,300 farms according to the data of the agricultural census of 1989[6] (INE 1991). This presents 76 per cent of the irrigated area (44,700 ha) in the whole Trás-os Montes area[7]. These 34,000 ha correspond to 27 per cent of the cultivated area (SAU[8]) in these zones. This irrigated area includes areas with annual crops, permanent crops and permanent pasture lands and meadows which have at least been irrigated one time in the agricultural year (DRATM 1991). These include summer and winter-irrigated areas (see Chapter 2.2). Further, a difference is made between irrigated areas and irrigable areas (*área irrigável*), respectively equal to 34,000 and 47,500 ha in these zones. In the agricultural census of 1989 the irrigable area is defined as the maximum area which in the agricultural year 1988/89 could -if necessary – be irrigated by means of the existing technical infrastructure at the farm and the normally available irrigation water. From this rather vague definition it does not become clear whether the difference between irrigated and irrigable areas refers to uncultivated land with irrigation potential, to water resources which are not used, to land equipped with irrigation infrastructure but which at the moment the census was taken, was not irrigated or to a combination of those. That makes it relevant to ask what could be considered irrigation in the context of Trás-os-Montes. For instance, are also lower lying wetter lands with high water holding capacity soils (*terra com lento* or *terra lenta*, literally ‘slow earth’) and/or fields which receive irregularly but purposingly run-off water when heavy rainfall occurs included in the irrigated acreage?

Indeed it is difficult to develop adequate statistical indicators that reflect real irrigation practice. Comparing the statistical data of 1979 and 1989 considerable differences emerge in irrigated areas whilst the stock of irrigation facilities has practically not changed. That is not only a question of differences in statistical definitions but also because of the complex reality of irrigation. First, there is a difference in the actual irrigated acreage and the acreage equipped with irrigation facilities. Second, the irrigated acreage changes from year to year in dependence of the available irrigation water, to name only one factor. So the apparent paradox can be explained that in ‘wet’ years the irrigated acreage is normally higher than in ‘dry’ years.

In this chapter on farmer-managed irrigation in Trás-os-Montes, the principles which underlie its functioning and its characteristics, in particular its complexity and dynamics will be described and analysed. First I will give a description of the context in which FMIS operate, the relevant characteristics of farming systems, irrigated agriculture and common features of irrigation systems. Then I will deal with the key elements that are strategic to the functioning of the irrigation systems and its diversity. Finally, the dynamics and stagnation in farmer-managed irrigation will be described and discussed.

Figure 2.2 Research area



Village numbers:

01 Corva	08 Tresmundes	15 Fervidelas	22 Soutelo
02 Sesmil	09 Sobradela	16 Adães	23 Galegos da Serra
03 Vila Cova	10 St. Marta do Alvão	17 Santiago	24 Vilalva
04 Lamas d'Olo	11 Meixedo	18 Vilela	25 C. de Vila de Castanheira
05 Covas	12 Torgueda	19 St. Marta	26 Vilar de Lomba
06 Bouça	13 Romainho	20 Aboboleira	27 Brito de Lomba
07 Seixedo	14 Pincães	21 Bostofrio	28 Roriz

The numbers in the Figure refer to villages in Table 2.7

2.2 Trás-os-Montes: diversity in agriculture and irrigation

Box 2.1 presents some relevant basic information for this thesis about the region of Trás-os-Montes.

The landscape of Trás-os-Montes is a succession of valleys, uplands and mountains. The region has a highly indented relief with considerable differences in altitude over short distances and a harsh climate with large spatial and temporal contrasts. People characterise the climatic conditions of their region by the proverb: '*Trás-os-Montes, nove meses de Inverno e três meses de Inferno*' (Trás-os-Montes: 'nine months of winter and three months of hell'). Rainfall is high in the cold winter but in the short, hot summer period the region dries out[9]. Throughout most of the region, about 85 per cent of the rainfall occurs in the period from October to May. During this period, irrigation of permanent meadows for hay production is a crucial farming practice. Good crop production in the summer period when water is most scarce could only obtained by using irrigation.

Box 2.1 Trás-os-Montes: Some basic information

What is to be understood under the region of Trás-os-Montes is not unambiguous. In the recent past Trás-os-Montes was considered as a province with an area of about 10,000 km^2. The province is no longer an administrative unit. Since the 1980s Trás-os-Montes has been combined with the neighbouring southern area of the Douro, to form the region of Alto Trás-os-Montes e Douro into two territorial units (NUTs). This region occupies an area of about 12,160 km^2 (resp. 8140 km^2 and 4020 km^2) and in 1996 had a total population of about 460,000 inhabitants (resp. 225,000 and 235,000) according to census data in Vilas Boas (1999).

Within the region as above defined, the Ministry of Agriculture (MAPA: Ministério de Agricultura, Pesca e Alimentação) is represented by its regional directorate (DRATM: *Direcção Regional de Agricultura de Trás-os-Montes*) and on a subregional scale by the *Zonas Agrárias*, bureaus of the DRATM corresponding more or less with the agro-ecological zones.

The research area is principally located in Alto Trás-os-Montes and coincides with the largest part of the district of Vila Real.

Administrative division

Trás-os-Montes consists of two districts: Vila Real and Braganca. Each district is composed of a number of municipalities (*concelhos*) which have elected administrative bodies (*câmaras*) controlled by the municipal council.

Since the 1980s municipalities obtained more funds and responsibilities to carry out public works like water supply, sanitation, roads, schools and public housing, education and medicinal services

Each municipality is further divided into a municipal town and a number of parishes (*freguesias*). A parish consists of one or more villages (*aldeias*) and hamlets (*lugares*). The Vila Real district consists of 266 parishes. The Parish council (*Junta de Freguesia*) elected by the inhabitants of the parish is the local government body administering the hamlets and villages comprising a parish. This elected body is subordinate to the municipal council (*câmara municipal)* and is responsible for the public affairs of the parish such as the control of local public properties.

Agro-ecological zones

The distinctiveness of Trás-os-Montes can be defended on several grounds: physical geography, regional flora, colonisation system including concentrated habitat, agrarian landscape, agricultural implements, ethnography, dialects etc (Portela 1991). Yet the region is not homogeneous. In climatological terms the most important concepts are *Terra Fria* (cold land) and *Terra Quente* (hot land).

For intervention purposes PDRITM divided the region Alto Trás-os-Montes e Douro into five agro-ecological zones (see Figure in this Box) with the following geographic and agronomic characteristics (World Bank 1982):

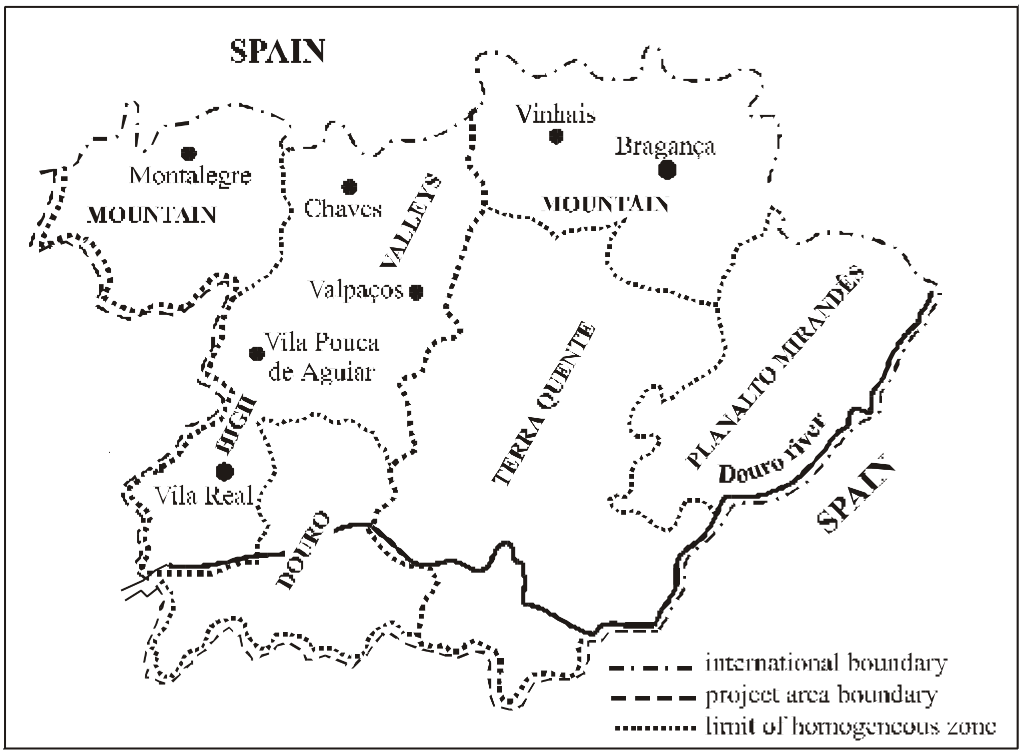
- The Mountains/*Terra Fria* with altitudes higher than 700 m comprises the *Terra Fria* (municipality of Braganca and parts of Vinhais), Barroso (municipalities of Montalegre and

Boticas) and parts of the municipalities of Vila Pouca de Aguiar and Vila Real. Great extensions of commons exist with crucial importance for agriculture and forestry. Cattle breeding is based on the use of the *baldios* and permanent meadows. Most important crops are rye and potato.

- The High Valleys with altitudes between 450 and 700 m principally comprise the region of Alto Tâmega (municipality of Chaves and parts of Valpaços) and Alvão Padrela (parts of the municipalities of Vila Pouca de Aguiar, Vila Real and Murça). Agriculture is more varied than in the mountains. Apart from cattle breeding with an important orientation to dairying, important components are also wine, olives and chestnut.
- The Planalto Mirandês (Miranda plateau) with altitudes between 700 and 750 m is relatively the most homogeneous zone. It comprises the municipalities of Mogadouro, Miranda do Douro and Vimioso. The extensive cultivation of rye and wheat is dominant. Relatively recently cattle breeding oriented to dairying has been introduced.
- The *Terra Quente* is the central hot and dry area with altitudes not higher than 500 m. It comprises the municipalities of Mirandela, Macedo de Cavaleiros, Vila Flor, Alfândega da Fé and Terra de Moncorvo. Apart from olive and wine, extensive cultivation of cereals and sheep husbandry are the most important farming activities. Due to the climate and fertile valleys the policy-makers and technicians ascribe to this area the highhest potential for agricultural production. State investments in irrigation development applied in Trás-os-Montes are highest in this zone.

The Douro is constituted by the valleys of the R. Douro and its tributaries with altitudes up to 450 m. The dominant activity is export-oriented (port) wine production in large estates and small farms.

Division of Trás-os-Montes into Agro-ecological zones



Much land is not or only marginally suitable for crop production (Agroconsultores-COBA 1991) because of steep slopes and soil characteristics (see Box 2.2). For instance, in the Alvão mountain zone of approximately 9300 ha, 22 per cent of the area is classified as having a moderate slope (8-15 per cent), 73 per cent has a steep to very steep slope (>15 per cent) and only 5 per cent has a gentle slope (4-8 per cent). This last category originally also had moderate to steep slopes but was transformed into terraces (Rosário 1990). Most soils are acid, thin and stony except in small areas near the villages which have been heavily manured for centuries. But what dominates is an extraordinary diversity in natural conditions (topography, soils, microclimates, hydrologic conditions), even within village areas over short distances.

Most of the region is made up of granite and schist formation, covered by alluvium in the open valleys. Conditions of water storage are favourable: the granite surface layers – altered by processes of erosion and weathering – function as a sponge and stores large quantities of water which are retained by the unweathered impermeable layers of the rock. The water stored in the winter and spring will slowly be released in the dry summer period through many small sources.

Box 2.2 Suitability of soils in the region Alto Trás-os-Montes e Douro

Agroconsultores-Coba (1991) made for the region of Alto Trás-os-Montes e Douro the following classification of the suitability of soils for different uses and its respective areas.

Suitability classes of soils and respective areas

Types of use	*Suitable lands*			*Unsuitable Lands*	
	Classes	*Areas*		*Areas*	
		ha	*% of total*	*ha*	*% of total*
Agriculture	High	10,200	0.8		
	Moderate	39,000	2.9		
	Marginal	209,300	15.8		
	Conditioned	41,800	3.2		
		300,300	**22.6**	1,009,000	76.1
Improved pasture	High	14,200	1.1		
	Moderate	99,500	7.5		
	Marginal	442,900	33.4		
		556,600	**42.0**	752,800	56.8
Forestry	High	28,800	2.2		
	Moderated	471,600	35.6		
	Marginal	721,400	54.4		
		1,221,800	**92.1**	87.600	6.6

Within the research area composed by the two agro-ecological zones of the Mountains and the High Valleys there is a large diversity in *ecological conditions* (principally related to altitude), *farming systems* (related also to the impact of development projects) and *irrigation potential* (related to differences in water availability and hydrological conditions). The most relevant differences between the Mountainous areas and the High Valleys are shown in Table 2.2 and Table 2.3.

Table 2.2 Relevant differences between the Mountains and the High Valleys

Characteristics	*Mountains*	*High Valleys*
a) Altitude	a) 800-1200 m	a) 400-800 m
b) Annual rainfall	b) 700-1500 mm	b) 500-1000 mm
c) Crop growth risks (frost, low temp., heavy rainfall)	c) Serious (maize, annual fodder crops). Short summer growing season	c) Less serious except drought. Longer summer growing season
d) Farm size*	d) average farm size: 5.7 ha 74% of farms smaller than 5 ha.	d) average farm size: 4.6 ha 84% of farms smaller than 5 ha.
e) Production	e) Rye/(seed) potatoes rotation. Permanent meadows (*lameiros*) and some forage crops. Communal lands (*baldios*) used for grazing and forestry.	e) Rye/potatoes rotation. (Annual) forage crops and some *lameiros*. Chestnut trees. Vineyards and olive trees. *baldios* less important for grazing.
f) Production orientation	f) Cattle raising oriented to produce meat.	f) Cattle raising oriented to produce milk.
g) Cultivated acreage (SAU)/ Total territorial area*	g) 23%	g) 49%
h) Irrigated area/Cultivated acreage (SAU)*	h) 50% (Barroso) 38% (Alvão/Padrela)	h) 19%
i) Hydrological conditions	i) Surface water dominant	i) Groundwater dominant: small scattered sources

* calculated from data agricultural census 1989 (INE 1991)

Examining Tables 2.2 and 2.3, the following observations are particularly relevant for this thesis:

- The ratio cultivated area/ farm area was between 70 and 75 per cent in 1989. This means that roughly 20-25 per cent of the total farm area which had been cultivated before, is not cultivated for economic, social or other reasons[10]. That indicates a clear tendency to extensification of land use.

- The dominance of permanent pastures and meadows in the cropped area of the Mountains.
- The winter irrigation of permanent pastures (*lameiros*) is dominant in the Mountains whilst summer irrigation is dominant in the High Valleys.

Table 2.3 Statistical indicators concerning agricultural production, irrigated crops and livestock in the Mountains and the High Valleys

Indicator (all values are in ha, numbers or %)	*Mountains*	*High Valleys*	*Montalegre (Mountains)*	*Chaves (High Valleys)*
Total territorial area	156,128	183,816	80,619	59,042
Total farm area	48,990	117,506	24,717	45397
No. of farms	7,112	14,797	3,007	6,486
Farm area/territorial area (a) [%]	31	64	31	77
Cultivated area (SAU)	35,960	89,990	18,080	32,371
Cultivated area/farm area [%]	73	77	73	71
Total irrigated acreage (b)	16,803	17,193	9327	7448
Irrigated area/cultivated area [%]	47	19	52	23
No. of farms with irrigated area	6,493	12,793	2,880	5,789
No. farms with irrig./no. of farms[%]	91	86	96	89
milk cows (>2 year)	2,856	4,106	1,110	2749
meat cows (>2 year)	11,780	5,817	6,866	1192
* cropped areas as % of SAU (c)				
rye & wheat	20	25	23	28
maize grain	11	3	9	6
potato	12	10	11	15
annual forage crops	4	3	4	4
fallow (d)	3	11	3	5
chestnut trees (e)	1	7	-	1
permanent pastures and meadows	43	19	46	20
temporary meadows	2	-	-	1
* irrigated as % of cropped area (f)				
maize grain	56	59	50	55
potato	48	68	35	66
annual forage crops	52	50	55	76
permanent pastures and meadows	73	39	94	37
temporary meadows	65	66	94	76
* irrigated area of principal crops (g)	16,569	16,389	9,321	7,116 (h)
area summer irrigation	5,526	(h)	1,997	5,559
% of total irrigated area	33	10,559	21	75
% of total cultivated area (SAU)	15	61	11	17
area winter irrigation	11,277	12	7,330	1,881
% of total irrigated area	67	6,634	79	25
% of total cultivated area (SAU)	31	39 7	41	6

Notes:

- The values have been calculated from data of the 1989 agricultural census (INE 1991). The statistical picture is somewhat distorted because farms with a SAU <1 ha are not included which still constitute a considerable number (about 30 per cent of the farms).
- It is assumed that the Mountains coincide roughly with the municipalities of Montalegre, Boticas and Vila Pouca; and that the High Valleys coincide roughly with the municipalities of Chaves, Valpaços and Vinhais. The municipality of Montalegre is the most typical representant of the Mountain areas while the municipality of Chaves is the most typical for a High Valley environment.
- (a): The difference is mainly explained by the big tracts of common lands in the mountains and the big-sized artificial lake in the middle of the Barroso region.
- (b): the irrigated acreage is mainly constituted by farmer-managed irrigation except an area of approximately 1000 ha near the city of Chaves (*Regadio de Chaves*) which is an irrigation system created and patronised by the Portuguese State.
- (c): crops with largest acreages. In the High Valleys also an important acreage of vineyards exists.
- (d): This fallow is alternated each every year with cereal. This rotation was normal in the past but now substituted principally by a cereal/potato rotation. Only in the municipality of Vinhais the two-year cereal-fallow rotation is still widespread.
- (e): chestnut trees are most widespread in the municipality of Vinhais. Chestnut was until the recent past an important element of people's and animal's diet.
- (f): most important irrigated crops
- (g): the values are slightly different from the total irrigated area because not all irrigated crops and their acreages are included, e.g. beans, vegetables, fruits which occupy small areas.
- (h): included in this figures are approximately 1,000 ha of the *Regadio de Chaves*.

General characteristics of farming in Trás-os-Montes

The majority of the total active population in Trás-os-Montes has always been engaged in agricultural production. In the beginning of the 1970s about 49,000 persons or 70 per cent of the active population was involved in agriculture according to census data. In 1981 this decreased to about 42,000 persons or 60 per cent (INE 1970; INE 1983). This is still extremely high by European standards.

Farmer households live in small villages (20-200 households) which are surrounded by farmland of all types. Smallholder agriculture is typical of Trás-os-Montes. Ownership by farmers of land and other farm resources is predominant.

The average size of the farms is about 6.1 ha for the whole of Trás-os-Montes but with great differences between and within agro-ecological zones. About 30 per cent of the farms have less than 1 ha and 64 per cent of the farms have less than 3 ha, which corresponds with about 16 per cent of the total cultivated area.

Farms are divided into numerous, dispersed plots: in the High Valleys and the Mountains an average of 13 plots per farm (INE 1991). A case study (Baptista 1989) of the village of Cimo de Vila de Castanheiro, nearby Chaves, revealed the existence of an agro-pasture-vineyard-forest area of 500 ha, propriety of 125 farming households, divided into 2700 plots scattered over the whole village domain. This corresponds with an average farm size of 4 ha and an average plot size of 0.18 ha. Irrigated plots are still smaller. 550 plots occupying a total area of 75 ha (average plot size: 0.14 ha) which corresponds to 15 per cent of the total cultivated area, have some form of irrigation.

The dispersion of plots and their ongoing division between heirs has a clear ecological rationale. The farming systems are built on the use of land resources with different qualities and natural conditions which are complementary in the realisation of the household objectives. That means access to each major type of land: gardens, meadows, pastures, grainfields, forests and vineyards. At the same time these different land qualities contribute to the reduction of production risks. An example is the general farming practice of cultivating potatoes in different places (irrigated and not irrigated), on different soils and in distinct periods.

Farming is mainly based on the use of natural resources and social networks at the local level. Farms essentially rely on family labour. Extra temporary labour needed for farm activities which have to be carried out in a short, concentrated time (planting, weeding, harvesting) is mobilised by labour exchange or more in general the exchange of other resources (e.g. water, draught animals, farm equipment etc) against labour. Casual wage labour complements the farm labour needs. Households are interlinked by multiple relations of mutual dependence. Socially regulated exchange of resources between farming households is crucial in the operation of farms, not only to mobilise labour in critical periods but also to overcome the shortage of land of particular types and characteristics (principally irrigated lands and meadows). Farm mechanisation forms a new but increasingly important part of exchange arrangements between households. Through these reciprocal relationships farmers mobilise and exchange resources[11]. This social mechanism is an important survival strategy for old people who are unable to work anymore.

Farming systems are not specialised: a combination of products, both agricultural and livestock, satisfies diverse household needs. At the same time, farmers use the variety of physical conditions (land qualities, soil properties, micro climates, available water, distance, access) to reduce risks and to make optimal use of the present farming resources. It explains the very intensive land and labour use on the best accessible and most productive areas.

A fundamental natural farming resource in Trás-os-Montes, particularly in the mountain areas are the commons or *baldios* (see Box 2.3). They are used for grazing, collecting firewood and raw material for the preparation of cattle beds and organic manure. Recently, under influence of modernisation projects, a marked differentiation in the importance and actual use of the *baldios* as a forage resource emerged depending on the production orientation (milk vs. meat production) of the farms and the number of small ruminants (sheep and goats) they hold. Milk production requires ‘better’ feed which makes the *baldio* as fodder resource superfluous. I will return to this issue in Chapter 5.

Most farms are weakly involved in input markets. Although the use of traditional techniques (e.g. animal traction) and inputs (e.g. dung) is still dominant, industrial ones (fertiliser, pesticides, farm machinery) are also applied. Some farming activities (e.g. rye harvesting, hay making) are increasingly mechanised although restricted by physical conditions like steep slopes, obstacles, walls, difference within and between plot levels, size of plots, width of rural and access paths etc.

Box 2.3 Baldios

Baldios are common lands that are traditionally administered by rural village communities and used by the local populations. The role of the *baldios* in the traditional agricultural system can be summarised with the help of four core concepts (Brouwer 1993a): *Pasture, outfield, reservoir* and *reserve*. First, cattle and small ruminants were pastured on the *baldios*. Second they functioned as outfields. On the *baldios* shrub was cut, with animal dung transformed into manure and transported to the particular owned arable plots, the infields. Providing fodder and soil fertility, the commons thus served as the outfields in an infield-outfield system. According to Slicher van Bath (1960:67, 283) up until this century this system could be found in many Western European countries. Through the yearly supply of these manure this fields maintained their fertility and physical qualities. It goes without saying that the commons have been a necessary condition for the reproduction of the agro-pastoral system. The *baldio* in the agro-pastoral system is the 'local factory' of fertiliser and draught force (Lima Santos 1990). Third, the commons constituted a reservoir of various important resources like wood, stone, fruits, herbs, animals and water. Finally, the commons functioned as a reserve which were cleared when the market, available labour force, technology (e.g. when chemical fertilisers became available) and the quality of the soil allowed this. In Trás-os-Montes poor people were temporarily allowed to cultivate small tracts of lands (*tapadas*) to cultivate rye. In Barroso, during the 1930-40s (see Lima Santos 1992) parts of the *baldio* were used for the cultivation of seed potatoes.

Exploitation and differential benefits
The *baldios* are typical common pool resources (CPR). In the recent past an elaborated system of rules existed to regulate the use of the *baldios* to avoid overexploration and to regulate the distribution of the resources produced by the *baldios*. These rules included regulating pasturing, limiting the cutting of brush and collecting of fire wood in time and space (*coutadas*) so that natural regeneration of the vegetation would be possible. Later developments (afforestation of the commons, emigration etc.) implied that these local rules became simplified, more loosely applied or even disappeared.
Despite it being a communal resource, not all members of a community benefited equally from its use. The derived benefits are directly linked to one's private property. The wealthiest farmers profit the most of the vast communal areas. An owner with a large herd makes more use of a communal pasture than his fellow commoner with only a few heads of cattle and as a big landowner cultivates more land, he needs more brush than the one that cultivates a small area.

Baldio area in time and space
Before 1900 large areas of the commons had already disappeared. The reduction of the *baldio* acreage in Portugal between 1875 (4,020,000 ha, about 45 per cent of the country's territorial area) and 1939 (407,000 ha, about 4.6 per cent of the country's superficie) with nearly 90 per cent is due for an important part to the land reclamation actions of large estate holders (Brouwer 1992). Also stimulated by campaigns of the State (*Campanha de Trigo*) they enclosed many commons for wheat growing also made possible by the availability of chemical fertilisers. Communal property also diminished through division among the commoners and the selling of parts by parish councils in order to finance communal and public investments.

Most of the remaining *baldio* land (90 per cent) is located north of the river Tejo, especially in mountain areas. In the Vila Real district the *baldios* occupy 25 per cent of the territory (in 1902 even 57 per cent or 247,000 ha (Taborda 1932: 79)). In the whole of Trás-os-Montes (districts of Vila Real and Bragança) *baldios* occupy an area of 180,000 ha on a total territorial area of 1,000,000 ha.

Afforestation and enclosure

Whilst in West Europe the communal ownership of lands disappeared almost completely in the beginnings of the 19th century, the commons in Portugal have been and are still a highly contested resource. For farmers it is an important part of their farming system. Foresters see the commons as a resource to extend the national forest area and to increase wood production. They also point out public benefits as the protection of watersheds, the purity of air, the existence of green spaces for recreation etc. (Brouwer 1995). In general, in engineering and political circles the *baldios* have been considered as unused and abandoned lands that need to be reclaimed for agriculture or forestry.

Since the 1930s the Portuguese State has prepared two projects through which it intended to put an end to the communal area that still survived. The first involved the afforestation of the commons by the State's forestry services, the second was the enclosure of some parts for agricultural purposes by the *Junta de Colonização Interna* (JCI). As a result, between 1939 and 1974 some 26,000 ha were privatised whereas most of the remainder was submitted to management by the state forestry service (Brouwer 1993).

The afforestation of the commons affected the livelihood of many rural people and generated a lot of, sometimes violent, protests. A large part of the communal lands was taken out of the control of local communities. In many cases the poorest, landless people lost their source of subsistence as the herding sheep and goats and the cultivation of small plots in the *baldios* was forbidden. Also the wealthier farmers were affected because pasturing of the commons by cattle was severely restricted.

The commons returned

In 1976, after the Carnation Revolution of 1974, a new law (*lei de baldios*) came into force which returned the *baldios* to the rural communities, the State forested part included. The 1976 legislation allows for two types of management by the communities: together with the State and independent of the State. In the first case the profits were divided between the community and the State forestry service. In the second case the communities could elect commoners' assemblies (*conselhos directivos* or *comissões de baldio*) which were responsible for the management of the commons and the application of financial revenues generated on communal land. Most villages opt for co-management with the State. In the Vila Real district, 193 *comissões de baldio* were created since 1976 of which 79 still were functioning in 1991 (Brouwer 1993, 1992). In case a *comissão de baldio* is not elected, the *juntas de freguesias* are in charge of the commons. In some cases contradictions and struggles emerged between the parish council and the *comissão de baldio* that controls vast areas and considerable financial resources.

Also on the national level many discussions have taken place about the juridical status and the exploration of the *baldios*. Since 1976 various political parties have made proposals to change the *lei de baldios*. A profound analysis of the struggle over the commons in Portugal can be found in Brouwer (1995).

Farmers produce for household consumption and for the market. Cattle represents the main relationship of the household with the market.

The specific balance between household consumption and market production depends on various factors such as household size, the demographic cycle of the household, off-farm labour and the resources (labour, land, water etc.) which the household controls. Farmers adjust themselves rapidly to new situations, e.g. if low prices occur for staple products like rye or potatoes, any marketable surpluses are used to feed cattle.

Many farmers raise cattle for meat and/or milk production, which constitute the most important source of agricultural income. For an evolution of the number of cattle in the Trás-os-Montes and in particular, the mountainous area of Barroso, see Box 2.4.

Box 2.4 Evolution of the number of cattle in the research area

In the whole Trás-os-Montes region the number of cattle increased from about 80,000 heads in 1979 to 92,500 in 1989 according to census data. The number of small ruminants (sheep and goats) increased in the same period from 233,000 to 306,000. The increase in the number of cattle was principally due to the increase of milk cows and young (< 2 years) cattle (INE 1982, INE 1991). However, there are different tendencies in specific zones. The evolution of cattle breeding in Barroso is represented in the Table below.

Evolution of the quantity of cattle between 1979 and 1989 in Barroso

	Municipality of Boticas			*Municipality of Montalegre*			*Total Barroso*		
	1979	1989	Var. (%)	1979	1989	Var. (%)	1979	1989	Var. (%)
Number of cattle farms	880	833	-5.3	2322	1917	-17.4	3202	2750	-14.0
Total number of cattle	3995	3926	11.0	11820	12429	4.9	15315	16355	6.4
Cattle >2 yrs	2318	2831	15.9	7847	7976	1.6	10165	10807	6.0
Milch cows	718	305	-61.0	725	1110	34.7	1506	1415	-6.0
Meat cows	1537	2526	39.0	7122	6866	-3.6	8659	9392	7.8
Bull	472	136	-71.2	897	719	-19.8	1369	855	-37.5
Small ruminants	6074	10050	65.4	29259	28084	-4.0	35333	38134	7.9

Source: RAC 1979, (INE 1982) and RGA 1989 (INE 1991)

According to INE data from 1968, 70 per cent of the farms in Portugal, concentrated in the Northern and Central parts, controlling 30 per cent of the cultivated area (SAU), mainly produce for household consumption (Sieber 1990). There is no reason to expect that this has changed in recent times, on the contrary. For many, agriculture has turned into a complementary activity in which production is mainly for household needs. Also because of very low farm incomes, since the 1950s a mixed economic strategy of pluri-activity and (temporary) migration of household members has become increasingly important for most farming households (see Box 2.5). This strategy can be summarised as:*'the land produces the daily food, the factory the monthly salary'* (Portela 1999). Off-farm activities are coordinated and interwoven with farming[12]. An important factor is the difference in mobility of labour resources within the household. Male and young adults are frequently engaged in off-farm activities while children, women and the old are working on the farm[13]. Farming represents security and a safety net in bad times. The effects of off-farm activities on farming are contradictory. Lack of labour will lead to a (temporary) extensification of land use. On the other hand, pluriactivity and (temporary) emigration of household members will contribute to income, to improve living conditions (housing) and will possibly lead to investment in farm development[14] (land, cattle, equipment, irrigation facilities). Pluriactivity has also implications for irrigation development as will be shown in Chapter 7.

Box 2.5 Pluriactivity of farming households

The pluriactivity of the rural households is a crucial phenomenon in the Portuguese agricultural sector. According to census data (INE: RAC 1979) approximately 82 per cent of the farms in Continental Portugal derive their total income from a combination of farm activities and additional activities and sources of income.
Also in Trás-os-Montes, in spite of the very limited opportunities outside agriculture, a large percentage of the farming households has more sources of income and activities. In the region of Alto Trás-os-Montes e Douro only 25 per cent of the farming households had agriculture as its exclusive source of income in 1979. Between the two territorial units however there is a sharp difference. In Alto Trás-os-Montes more than a third of the farming households had agriculture as its exclusive source of income, in the Douro only 15 per cent (Portela *et al.* 1992). In 1979, about 45 per cent of the farming households in the region obtained more than 50 per cent of their income outside agriculture but with a great diversity between the different zones in the research area as the Table below shows. In 1989, this value increased to 53 per cent.

% farmers households whose income derives for more than 50 per cent outside agriculture

		1979	*1989*
Mountains	Boticas	7,0	
	Montalegre	29.1	
Hig Valleys	Chaves	34.6	
	Valpacos	28.3	
	Vila Pouca de Aguiar	33.2	53.5*
	Vila Real	54.4	

Source: RGA 1979 (INE 1982)

Source: RGA 1989 (census data quoted in Pires *et al.* 1996). The average value of 53.5 per cent obscures a variation between very small farms and large farms: between 73.9 and 25.0 per cent.

The income sources for many farming households are very diverse e.g. wage labour, principally in the construction sector; social security payments; interest on bank accounts gained abroad; land rents etc.
Portela (1981) and Baptista *et al.* (1993) show in detail the interconnections between pluriactivity and farming in terms of saving, investments and consumption for the villages Fragueiro and Couto de Ervededo. They conclude that it is impossible to understand farming and rural development perspectives in Trás-os-Montes if disconnected from the phenomena of pluriactivity and emigration.

From this description of general characteristics of farming in Trás-os-Montes it can be concluded that mixed farming and a high diversity of activities is purposely aimed for, according to the possibilities to do so. Diversification is a way to minimise risks and income variations, to adjust to natural variability and to make an integral use of resources and intermediate products.

The role of irrigation in local farming

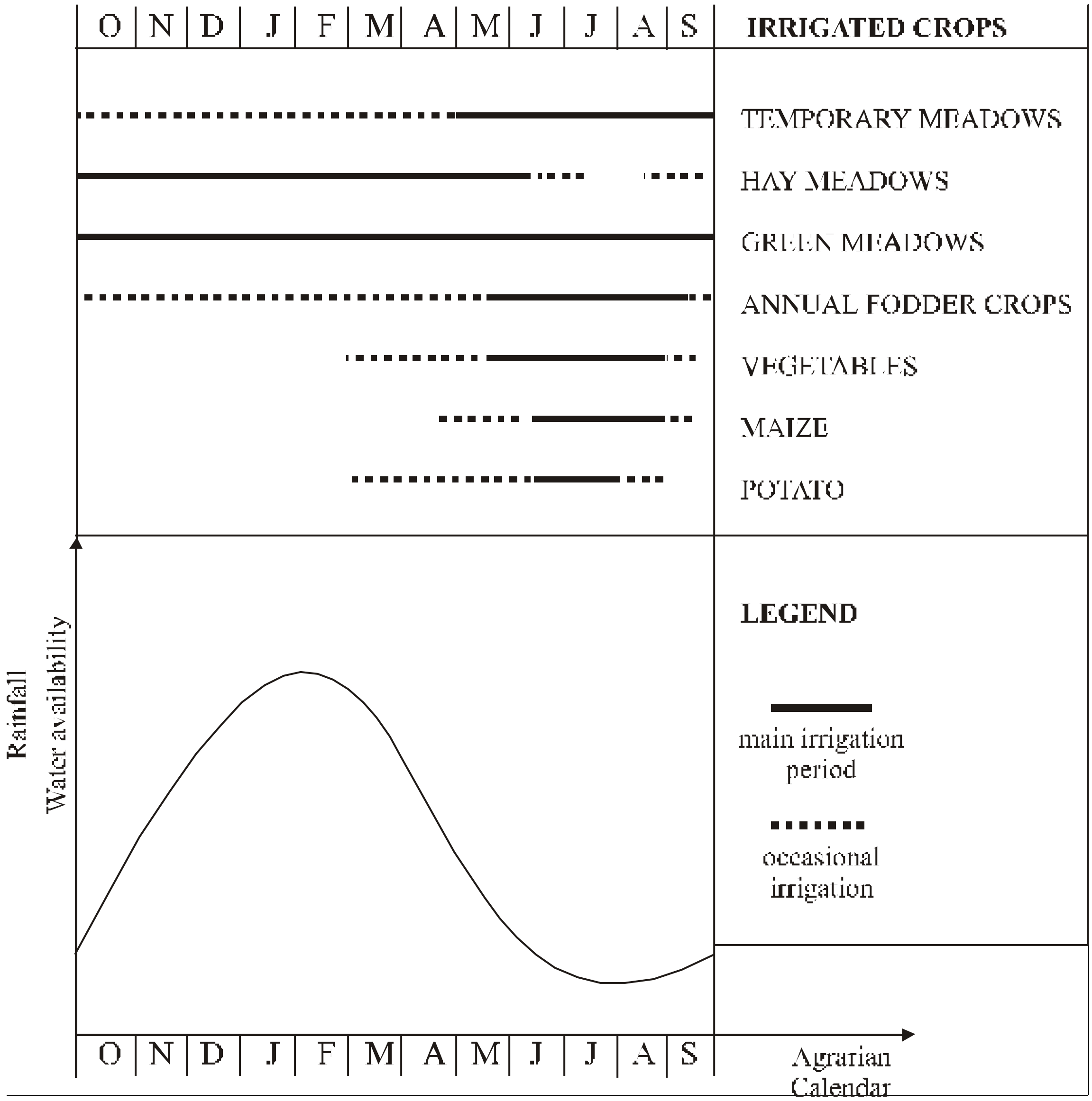
Irrigation in Trás-os-Montes is a crucial resource in farming for the following reasons:

- Household consumption depends on irrigation of staple foods (potatoes, maize) and horticultural products[15]. Production for household consumption is crucial for many households (in particular for the old) for lack of other sources of income. A case study of the production strategies of dairy farmers in the village Cimo de Vila de Castanheira (Baptista *et al.* 1990) shows that production for household consumption represents about 50 per cent of the total production value of the most common group of small dairy farmers (with 1 to 3 milk cows).
- It is a decisive factor in fodder production for cattle. The production of hay which is the basic animal feed in most farming systems, is dependent on irrigation in winter and spring. The importance of this ‘winter’ irrigation, particularly in the Mountain areas was already revealed in Table 2.3: winter irrigation represents 2/3 of the total irrigated area in the Mountains. Other forage crops, totally or partly dependent on irrigation in the summer (fresh grass and annual forage crops such as turnips, beet, (silo)maize, milled corn etc.), constitute important complements in balanced cattle feeding, principally concerning milk production in the High Valleys;
- It is a crucial local resource in agricultural intensification and development. Agrarian development programmes stimulate the emergence of specific farming development patterns, aimed at an intensification of cattle-raising and fodder production. In turn these will create specific demands on the availability of irrigation water, irrigation practices and the functioning of irrigation systems. So, irrigation development will be an important support component of diverse agrarian development patterns. In chapter 5, the role of irrigation in two contrasting farming systems in the mountain area of Barroso will be analysed in more detail.

A good indication of the importance of irrigation is both the general willingness of the farmers to improve their collective systems and the specific investments that they make in opening up new water sources for irrigation purposes and/or the improvement of existing water sources (Portela 1990; Prins 1991; Davidse 1991)

Irrigation is practised throughout the year, both in summer and in winter (Figure 2.3). In the dry summer water deficits frequently occur. Arable plots with maize and potatoes and home gardens with vegetables are irrigated during June-September, the period with limited and irregular rainfall. Summer irrigation is mainly supplementary, providing water to crops which germinated on water stored in the soil profile, originating from earlier rainfall. The variability of crop water requirements in Trás-os-Montes is large both in space and time (Sousa 1990). Pastures are irrigated less frequently in summer and the pasture area irrigated in summer is much smaller than in ‘winter’ for three reasons. First, irrigation water is scarce; second, irrigation water used for arable crops and domestic consumption has priority over pasture irrigation and third, pasture can survive long dry spells (although this will affect yield) whilst arable crops already would have wilted. Only one type of meadows, the *segadeiras* – small plots for cutting fresh grass – are intensively irrigated during the summer period (see Box 2.6).

Figure 2.3 Irrigation during the agrarian calendar



Notes:

* Occasional irrigation: where needed during dry spells in the wet period or during the summer period if water is available

* Irrigated crops:

- Potatoes: planting in March/April and harvest in August/September. Primarily for household consumption. Surplus is sold or used as cattle feed.
- Maize: sowing period from May/June until September. Maize is cultivated (mostly in combination with beans) for human and animal consumption. This corresponds to 4 different modes of use:

- grain maize (*milho para grão*) for human consumption (bread or *pão*)
- green maize (*milharada*) for animal consumption
- silage maize for animal consumption
- a combination of grain and green maize (*milho basto*). Maize is thickly sown and weeded and thinned out during the growing season to provide fresh cattle feed. In dependence of the availability of irrigation water some grain maize could also be harvested.

To the maize cultivated for bread more labour (weeding) and irrigation water is allocated.

- Vegetables (onions, tomato, garlic, lettuce, carrots, cabbages, beans, paprika etc.): planting and sowing during the whole spring and summer in small garden plots which constitute a sort of store room for the women.
- Annual fodder crops (irrigated: turnip, annual grasses, fodder beets; rainfed: green rye, barley, oats) sowing dates depending on type of crop. Turnip and annual grasses (*erva molar, azevém, erva castelhano*) are sown in August. These crops are pastured and/or harvested in the winter and spring.
- Permanent green meadows: small plots with fresh fodder
- Hay meadows: for hay and pasturing
- Temporary meadows: for hay and pasturing

* The figure is a highly schematic representation of the irrigation periods of different crops. Crop rotations and sowing/planting dates are different for the Mountains and the High Valleys. Agronomic practices are complex and flexible.

'Winter' irrigation (called *rega de lima*) is only applied to permanent meadows[16] (called *lameiros*), especially in the agro-ecological zone of the Mountain Areas. In the context of irrigation the whole period from October to June is called 'winter' in Trás-os-Montes. These *lameiros* are a fundamental pillar of local farming systems as a main source of cattle feed in the whole year (pasturing) but particularly in the winter (hay). The management and the diversity in use of these permanent meadows require a detailed knowledge of local field conditions and constitutes an outstanding example of skill-oriented farming technology in Trás-os-Montes (see Box 2.6).

Irrigation is essential for the productivity and quality of a *lameiro*[17]. Considering the lot of work necessary in hay making, irrigation is also a decisive factor to enhance the productivity of farm labour. Farmers say: 'one never sees a good meadow above the channel' (Morgado 1993). Two periods can be distinguished in meadow irrigation: the winter period and the period from March to June when the hay grows.

In the winter and spring (night) frosts occur frequently, up to 60-80 frost days/ year. Normally, frosts begin in mid-October and end at the beginning of May but frosts may occur earlier and later. The irrigation water prevents the grass from freezing, enabling rapid regrowth during spring.

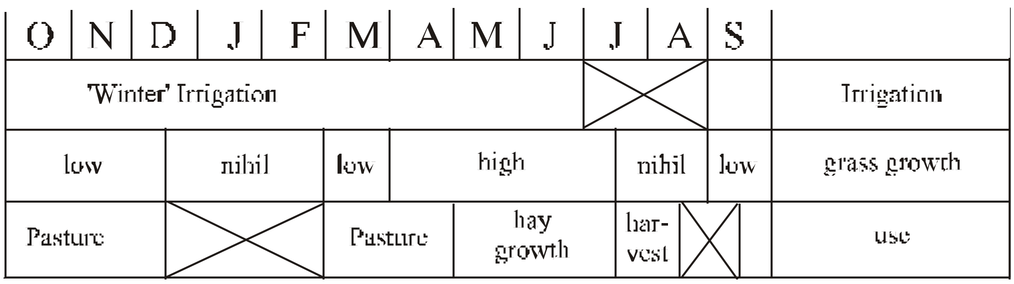
Farmers also emphasise also the manuring value of the water[18]. During the heavy rains in the winter fine soil particles and manure are taken up, transported and deposited by the water. Also the cow dung on the village streets is washed away. This *agua de surra*[19] is intentionally led to the *lameiros* located more downstream[20]. Bennema (1978:70) mentioned the use of ashes from burnt parts of the *baldio* of Marras. In this village a part of these ashes comes down with brook water and this muddy water is spread over the adjacent meadows.

Box 2.6 Lameiros and their Diversified Uses

Stretches of *lameiros* or permanent meadows constitute one of the very typical components of the Trás-os-Montes landscape. They are to be found principally near streams and other water sources. Most of the *lameiros* are irrigated but dry-land *lameiros* also exist. They are constituted by natural grasses (*gramíneas* and *leguminosas*) which emerge after cultivation of land has ended or when herbaceous vegetation is destroyed by fire. Although these meadows are not sown, they are actively managed (Peixoto dos Santos 1995). Farmers husbandry practices include the selection and spreading of grass seeds (from hay), fertilisation (manure and/or fertilisers), the destruction of weeds, cleaning of leaves, drainage and irrigation. When the quality of the meadows has become very low they are renewed (*anovar*) by cultivation of potato and/or rye for one or two years.

Together with the *baldios* the *lameiros* traditionally constitute the most important source of fodder in Trás-os-Montes cattle breeding. *Lameiros* are used for grazing, cutting fresh grass and hay making. In function of these different uses, farmers distinguish different types of *lameiros*. According to Portela (1988), farmers in the 'Terra Fria' or 'cold land' (roughly coinciding with the municipalities of Vinhais and Braganca) call these *passigueiros, segadeiros* and *lameiros-para-feno* respectively. *Passigueiros* (called *lameiros de pasto* in Barroso) are typically meadows that are used only for pasturing. On the contrary *segadeiros* or *lameiros de erva*[21] are only used for cutting fresh grass during the whole year, albeit principally in the summer. The fresh grass is provided to stabled cattle at the farmstead. In order to save time and energy in transporting the grass, only meadows are selected which are located at productive plots near the farmstead. *Segadeiros* occupy small plots but they are very intensively fertilised and irrigated. The *lameiros-para-feno* or *lameiros de feno* are the most widespread and important. They are used both for grazing and hay-making. The production of hay is the most important of those and the major period of productive grass growth is reserved for that. A rough picture of their use in time (see Figure below) is the following: normally in July/August the standing grass is cut, dried and transported to the farmstead. Afterwards they can be grazed in the periods just before and after the Winter, respectively September-November and March-April. Then the grass-growing period for one cutting of hay will initiate in the period that cattle will not be allowed to graze on this type of meadows.

Use of *Lameiros-para-feno*



The type of use of a given *lameiro* may vary over time, e.g. a *lameiro-para-feno* in one year may be a *passigueiro* in the next and vice-versa. Within the same meadow plot the type of use may vary as well because of topographic factors. For instance, in a sloping meadow plot the higher part may be grazed throughout the year, the middle part used for hay-making and the lowland used for the collection of fresh grass. The concrete use made of the *lameiros* depends on many factors and changing conditions. Irrigation, location and distance to the farmstead (village) are already mentioned. For grazing of work animals it is convenient to have a *lameiro* near the farmstead. The location of the *lameiro* will also determine the hours of sunshine received, occurrence and duration of frosts, irrigation opportunities and consequently the type of use. To irrigate a distant meadow some hours of walking may be required. Conditions of access may determine its use. Narrow paths bordered by stone walls, trees and bushes would make the transport of hay difficult. Topography is an important determinant in the quality of a *lameiro*. Steep slopes and convex landforms create shallow soils with a shallow root zone, low soil moisture capacity and nutrient availability. At concave slopes and depressions there is an accumulation of fine soil particles and deeper rootzones. Waterlogging occurs frequently in the *lameiros* situated in the lower parts. Drainage conditions (poorly, normally or excessively drained) of the *lameiro* could determine its use and exclude others (Portela 1988).

The lack of labour as a consequence of emigration has led, on the one hand, to a slackening of husbandry practices e.g. a decreasing frequency of renewing, less destruction of infestants. It has led on the other hand to an increasing mechanisation of farm work, in particular the preparation and collection of hay. Therefore criteria such as drainage conditions, size and topography (regularity, slope) of meadows as well as access to them are becoming more important.

Lameiros that fail to satisfy these criteria are increasingly used more extensively, e.g. only used for pasturing. On the other hand, precisely the mechanisation of hay-making and harvesting permits an increase of the *lameiro* area. This allows various categories of farmers which are not even cattle breeders but have a shortage of labour force (old farmers, pluriactive farmers), to valorise a part of their former arable fields which would otherwise be difficult. The produce of the *lameiros* is sold or more frequently exchanged for other resources such as animal traction, use of farm equipment, manure etc. The increase of the *lameiro* production is an important factor in explaining the increase of cattle in recent times.

Furthermore the wet conditions are hypothesised to positively regulate the composition of plant species in the pasture (Gonçalvez 1985).

This irrigation practice can also be interpreted as a water-spreading technique that stores water in the soil profile and groundwater aquifers which during the summer period will be gradually released to recharge water sources such as springs and wells.

2.3 Common features of farmer-managed irrigation systems

Water sources

Generally, a multitude of water sources and irrigation facilities exists within the village domains. A classification of water sources includes:

- small streams (rivers, brooks). Some have a permanent streamflow but most have a substantial flow in the winter period but small to nil flow in the summer. In some cases substantial reserves of water are stored in pools of the river bed. Water from a stream is diverted to a channel by a small weir, sometimes a permanent structure but often a temporary structure, which needs regular repair and sometimes entire rebuilding.

- springs (*nascentes*) which are groundwater sources coming to the surface. The small discharges (0.1-1 l/s in summer) are normally stored in nearby concrete reservoirs (*tanques*) or earthen ponds (*poças*[22]) with capacities up to approximately 150 m^3. In Trás-os-Montes, these reservoirs could have various, sometimes combined functions which will be dealt with in detail later in this thesis. Most frequently reservoirs are used to accumulate water to a volume which is sufficient for field irrigation and to diminish relative transport losses in the channels. Water from these reservoirs is either used directly on the fields below or transported by a channel, sometimes in combination with the discharge of other sources, to more downstream fields.
- galleries, which are horizontal tunnels dug into the mountains (up to 100 m of length) in order to capture more water from groundwater aquifers. Farmers call these tunnels *minas* (literaly: mines). They have been introduced when the Arabs occupied Portugal. This technique resembles the *qanat*[23] system, used all over the Middle East, North Africa and Central Asia (Iran, Pakistan and Afghanistan) to provide water to agricultural lands (Prins 1991).
- shallow wells to a depth up to approximately 15 meters. They are more frequent in uplands (*planaltos*) and valleys. In the past, instruments moved by man or cattle have been used to bring water to the surface. Recently small pumps driven by fuel or electric motors are used.
- Tubewells to depths up to approximately 70-80 metres equipped with pumps and electric motors.

All these sources contribute to the overall availability of water which is captured and delivered to a specific combination of crops and plots for every farm. In Box 2.7 a concrete example is shown of this combination of crops, plots and irrigation water sources. In this example, 15 plots with meadows (*lameiros*, pasture) and different annual crops (maize, potato, vegetables), are irrigated by 8 different sources.

Two *hydrological characteristics* of the water resources in Trás-os-Montes are highly important: the *variability* of water flows during the agrarian calendar and the high *interconnectivity* of water sources.

As the summer progresses, water availability decreases, especially in the High Valleys (scheme flow generally: <<5 l/s). Related to water availability another relevant difference in hydrological conditions exist between Mountains and High Valleys: surface water sources such as small rivers and brooks (*ribeiros, ribeiras, corgos, regatos, rigueiros*) are dominant in the mountains while in the high valleys principally small, scattered sources (springs, wells) originating from subterranean water are used. For a summary of the most relevant characteristics of the different water sources, see Table 2.4

Box 2 .7 A combination of crops, plots and irrigation water sources

List of the fields of Mr. OSG, Romainho (a)

Plot nr. (b)	*Land use type*	*Name location*	*Area (in m²)*	*Crops*	*Water Source*
3955	Terra e videiros	Cotos	1,890	maize, rye	4 poças (c)
3960	Terra e lameiro	Cotos	5,810	rye, grass	4 poças (c)
3965	Terra de Pasto	Cotos	9,500	Pasture	4 poças (c)
3972	Terreno de Pasto	Cotos	12,000	Pasture	4 poças (c)
3974		Val Cabras	11,200	forest (pines)	4 poças (d)
3981		Val Cabras	15,375	Pasture	4 poças (d)
4039	Lameiro	Fojo	5,226	Pasture	Poça de corgo (e)
4041	Lameiro	Fojo	2,963	Pasture	Poça de corgo (e)
4137	Terra	Lameiras	576	Pasture	Mina (f)
4147	Terra	Lameiras	265	Pasture	Mina (f)
4159	Terra e Lameiro	Porto	2,823	Maize Pasture	de cima (g), poça de corgo (h)
4290	Terra	Nabal	180	Vegetable garden	de cima (g)
4310	Terra e terreno	Porto	4,980	Pasture	Poça de corgo (h)
4331	Terra e lameiro	Veiga de Baixo	1,269	maize, potato, pasture	de cima (g)
4381	Terra	Palvites	1,476	olive trees	– (i)
4387	Terra	Palvites	4,982	olive trees	– (i)
4441	Lameiro	Vinganda	7,526	Pasture	Nascente (j)
4530	Terra	Fontelas	572	rye, pasture	Nascente (k)

Notes:

- (a): based on Boelee (1992)
- (b): The original list dates from 1951 and has been written by an employee of the tax administration in Boticas. The numbers refer to the land register.
- (c): spring-fed reservoir, 5 users
- (d): spring-fed reservoir, 2 users
- (e): reservoir in stream, downstream of the five-poça system in the ‘Corgo do Muro’
- (f): gallery, property of OSG
- (g): communal irrigation system
- (h): probably another source than (e) is meant
- (i): without irrigation
- (j): spring
- (k): spring

In Trás-os-Montes water sources are highly interconnected within village areas and less frequently between village areas in case of surface water. Therefore applying the concept of ‘water losses’ to justify intervention in the irrigation systems often makes little sense: the ‘loss’ of a water source is often the ‘gain’ for another. Local water rights are based on this reality. I will come back to this issue in Chapter 6 in which irrigation interventions are considered.

Table 2.4 Characteristics of water sources

WATER SOURCES CHARACTERISTICS	*Streams*	*Spring*	*Gallerie*
Water availability in Winter	high	medium	Medium
Water availability in Summer	very low to high	low to medium	low to medium
Variability of flow	high	medium	medium
Temperature fluctuation	high	low	low
Manuring value	high in winter	low	low
Intake facility	diversion weir*	-	-
Storage needs	depend (a)	reservoir needed	reservoir needed
Access/property regime	public/communal	publ/com/group/ind(c)	group/individ (d)
Required local labour input	low to high (b)	low	high in construction
Required capital input	low to high (b)	low	local materials
Required external inputs	low to high (b)	low	yes (e)
Exploration cost	low to high (b)	low	low

Notes:
* :Also use of (mobile) motor pumps and pvc tubes
(a): The most important factor is the summer streamflow. If the streamflow is low then storage is necessary.
(b): It depends on the type of weir. If it is a permanent concrete weir, construction costs and initial inputs are high but maintenance and exploration costs are low. If the weir is a temporary one, exploration costs are high because it needs to be build up frequently with local labour and materials.
(c): Access depends strongly on the location of the spring. In many cases local rules exist or have existed which regulate the use of a spring, even if it is located on individual owned land.
(d): Making a gallery (*mina*) is typically an individual or group investment.
(e): Formerly, experienced specialists (*mineiros*), particularly from the Minho region, were contracted to orient the work. Nowadays galleries are hardly made because of the high cost. If they are constructed, then mostly with modern drill technology.

WATER SOURCES CHARACTERISTICS	*Shallow Well*	*Deep well*	*Dam and reservoir*
Water availability in Winter	n.a.	n.a.	high
Water availability in Summer	low to medium	medium to low	high
Variability of flow	low	very low	can be regulated
Temperature fluctuation	low	low	high
Manuring value	low	low	low
Intake facility	motor pump	electro pump	dam outlet
Storage needs	no	no	n.a.
Access/ property regime	individual/group	individual	collective
Required local labour input	high	no	no
Required capital input	med. (pump and tubes)	high	very high
Required external inputs	no	high (drilling)	very high
Exploration cost	medium (pumping cost)	high (pumping cost)	high

Notes:
- Streams, springs, galleries and shallow wells are the most common traditional irrigation sources. Tubewells and dams have recently been introduced.
- The water of springs and galleries are particularly appreciated in winter irrigation because of their higher water temperature in comparison with surface water. Gonçalvez (1985: 31, 32) measured differences in temperature of more than 10 ^{o} C.

- The use of wells is relatively expensive because of the need for energy to lift the water.
- Shallow wells are most frequently found in the High Valleys.

Irrigation systems

Two characteristics of the irrigation systems in Trás-os-Montes are essential to understanding their functioning. First, *water supply is highly variable in time*, both in the course of the year and between the years. It is determined by natural factors. In that sense the irrigation systems are supply driven. It means that in times of water shortages water demand and irrigated area necessarily have to adapt necessarily to the scarce water supply[24]. It follows that in 'wet' years irrigated areas are normally larger than in 'dry' years.

Second, as in many farmer managed systems worldwide, water distribution is not based on the water requirements of certain crops, but on the *social agreements about the sharing of a scarce resource*. In this way, every farmer knows beforehand which share of the available irrigation water he or she will receive in the summer although the quantity of available irrigation water cannot be known exactly. Dependent on the precipitation regime of the foregoing winter season the farmer – on the basis of his experience- will make an estimate of irrigation water, available to him in that summer season. This will be reflected in the cultivated crops and their cropped areas. Also, in this way irrigation systems divide any water shortage equally among the farmers roughly in proportion to their water rights.

Water shortages increase sharply during the summer and also tensions regarding the use of water, rise. The available irrigation water flows diminish while crop water demands rise. In contrast to the winter period when water is abundant, during the summer period the division of water is arranged via more restrictive rules.

Water management is based on various allocation principles, which define the kind of water rights in the system. In Trás-os-Montes four basic allocation principles have been identified. The established water allocation schedule is translated into physical water distribution by means of distribution rules and infrastructure.

In case the water source is flowing surface water (small streams, brooks) serving more irrigation systems, generally two rules regulate the access to water (Bleumink *et al.* 1992). First, the so-called sequential water right means that a (group of) upstream user(s) has the right to divert as much water as they want. Such a right can be realised with a diversion structure and a canal system. Water that is not diverted and drainage water can be diverted by user(s) more downstream and so on. The second rule is that one may only construct a new diversion structure if this does not influence the water availability of other, already existing diversion points. In some small river basins, a governmental river guard (*guarda rios*) supervises the observance of this rule.

A striking feature is the complexity of the water uses and irrigation networks at village and intervillage level. Apart from irrigation, water is also used for washing, cattle watering and to drive mills[25]. Mills could affect the water availability of nearby irrigation systems since water has to pass through the mill and a considerable head loss (difference in upstream and downstream water level) is needed for its functioning. This head loss could make it impossible to irrigate plots next to the mill when it is in operation. Some water sources are used to supply drinking water to home connections in the villages. In other villages water is stored in reservoirs for public use, e.g. to extinguish fire.

The irrigation networks consist of different water sources scattered in the territory of the village, reservoirs, canals and fields, in different ways interconnected which at first sight give a chaotic impression. Some fields could be irrigated by more than one irrigation network. Often, distinct irrigation systems have various water sources, e.g various springs or a spring and a brook. The complexity increases further when one or some of these sources alternately are part of more irrigation systems (Portela 1988: 207). In the winter period many systems are also fed by temporary drains.

Interwoven with this complex interrelated irrigation infrastructure is farmer's access to irrigation water under different property regimes. They may be owners or co-owners of water sources and irrigation facilities. It is possible to distinguish irrigation systems which are owned and operated by individuals, (family) groups or the whole community. The contribution of these schemes to the overall water availability at farm level is specific for each farmer. Access to water can also obtained by renting irrigated land, buying water, exchange of resources, the use of emigrants water etc.

In most villages, one system is referred to by the inhabitants as the communal irrigation system (*levada* or *rego do povo*). The definition of such a system is not very precise but four elements are common. Such a system generally has a long history, at village level it covers most water users[26] and irrigates the largest area – summer irrigation is taken as the reference – and uses the principal water source(s) of the village. Moreover they are all gravity systems and depend on water sources with variable water flows during the agrarian calendar. In the Mountains the communal irrigation schemes are much more important than in the High Valleys. This thesis focuses on this type of systems.

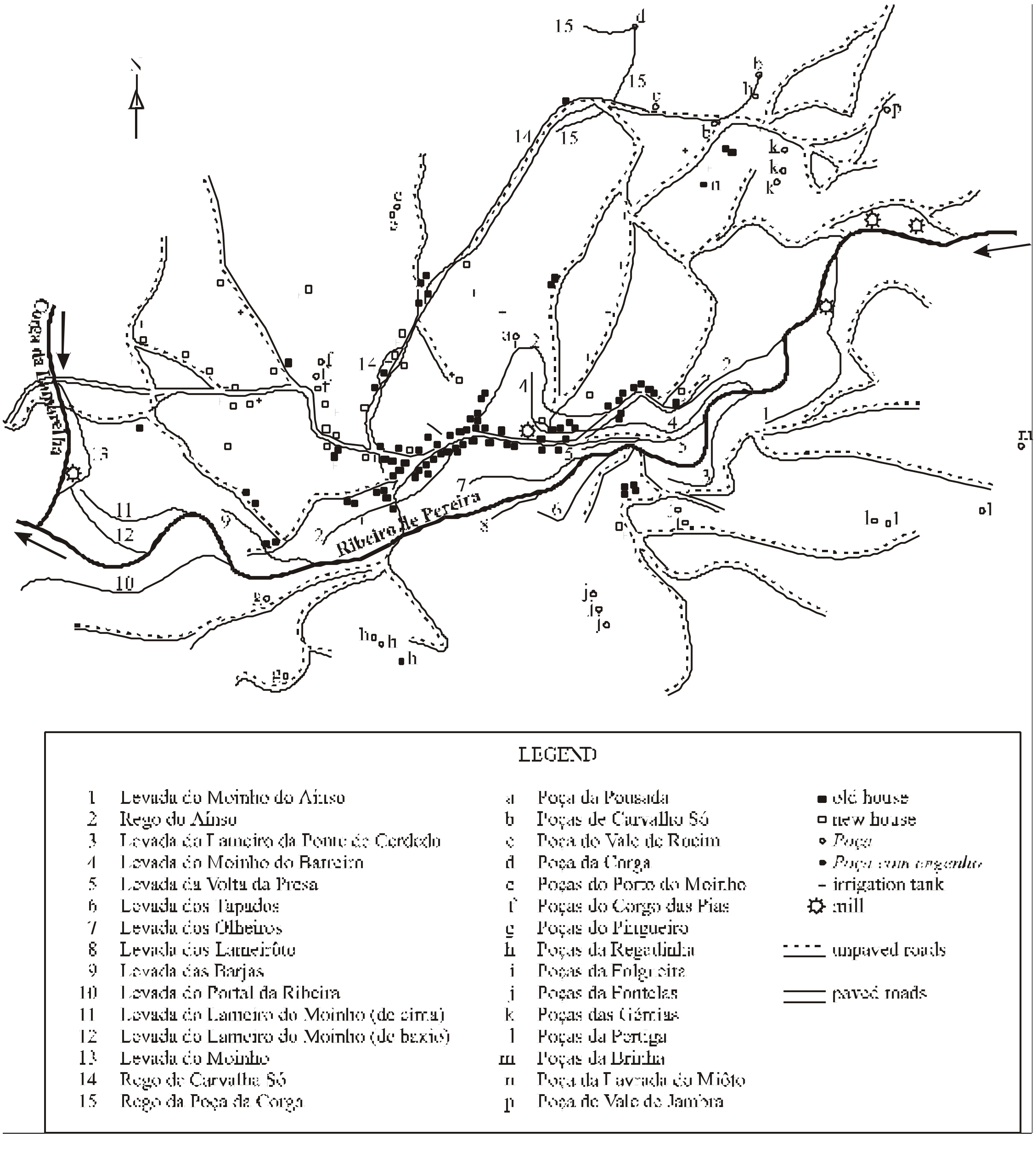
In a sample of 28 villages studied[27] (see Table 2.6), the irrigated areas (summer and winter included) of the communal systems ranged from 2 to 35 ha per system; the number of water users from 8 to 104 per system. The systems are typically village-based resources: generally the areas irrigated by communal systems are limited to the village domain, thus the geographic and demographic dimensions of the irrigation systems normally coincide[28]. It should be stressed, however, that besides the main communal system, other small communal systems and many smaller group, family and individual irrigation facilities can often be perceived at village level, the importance of which may on the whole surpass that of communal systems, especially in villages in the High Valleys. Bleumink and Kuik (1992) provide summaries of the number of water sources in the villages, subject of the first inventory studies.

In some villages more than 100 small water sources were present. For an example of irrigation systems at village level, see Box 2.8. The whole of irrigation infrastructure on the village level can be perceived as the result of a historical process in which the different irrigation facilities have been created, extended and superimposed in time. At the same time specific interrelations and interferences emerged and developed between the systems.

Box 2.8 Irrigation Systems in the village domain of Pereira (Adapted from Peixote dos Santos 1995)

In the village Pereira, *freguesia* de Salto, *concelho* de Montalegre are living 33 farming households. At the level of the village area can be distinguished (see Figure below):

- 4 communal systems
- 12 canals (*levadas*) for winter irrigation (on average 3 water users per canal)
- 30 unlined reservoirs (*poças*) fed by nearby springs (on average 2 users per spring). Two of them are equipped with a self-starting siphon (*pedra de engenho*)
- 26 concrete reservoirs connected by (long) PVC lines to springs in the *baldio* area (individual use).



Field irrigation practices and methods

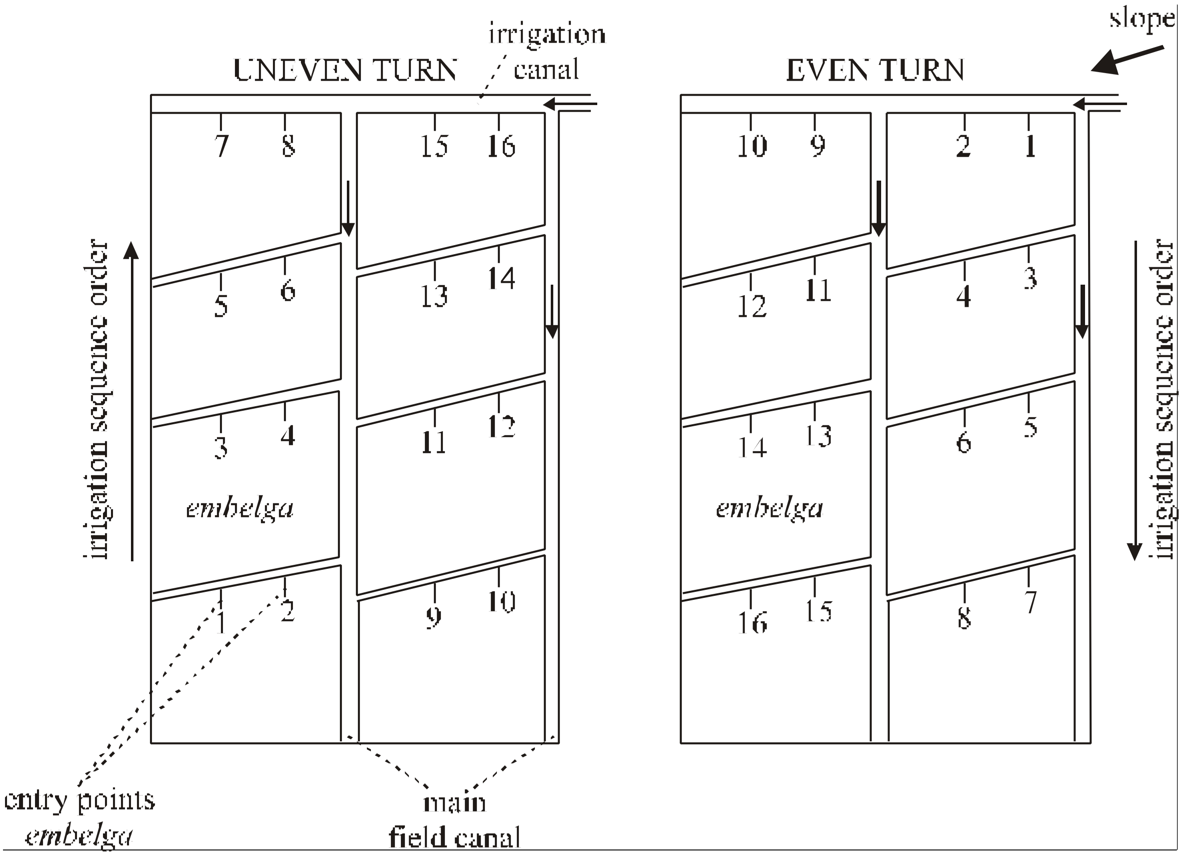
Summer irrigation areas (*veigas*) are always located near the villages. In areas with steep slopes they form an authentic man-made terraced landscape with numerous walls[29]. Plots are small to very small[30] (most frequently 0.05-0.2 hectares with extremes of 5 m^2 to 0.5 hectares), often irregularly shaped with varying slopes. The plots consist of man-made soils which have been heavily manured for hundreds of years with a mixture of cattle dung, straw and vegetative material gathered from the common lands (*baldios*). These plots are cultivated very intensively both in land use and labour input in a way that can best be compared to gardening. They are cultivated throughout the whole year. After the harvest of the summer crops the plots are often sown with crops which produce cattle fodder in the winter and spring. Annual grasses (*azevém, erva molar*) are already sown in the summer crop before its harvest. Other examples of these crops are turnips, rye, barley and oats which are used as green fodder.

Surface irrigation methods in Trás-os-Montes

In Trás-os-Montes farmers apply almost all irrigation water by surface methods: controlled flow irrigation or *rega por embelga* on soils of lighter texture and furrow irrigation on more heavy soils. The use of these irrigation methods requires much skill and labour, not only in the shaping and preparation of the irrigated plots but also in the application of water ('irrigating'). It is an outstanding example of skill-oriented technology combining simple instruments with experience-based knowledge. In the *embelga* irrigation method the field is divided into small basins or borders called *embelgas* which are surrounded by bunds (see Figure 2.4). Within the field the irrigator is guiding the water with a hoe (*enxada*), opening and closing furrows and checks, microlevelling ground surfaces etc. in the way that water will cover the whole field.

In the furrow irrigation method the units are short furrows (about 10-120 m) which are blocked at the end. Common practice is to irrigate one unit (*embelga* or furrow) after the other if stream flow is not too high. The irrigator will cut off the supply when the water has covered the *embelga* or when the end of the furrow is reached.

Figure 2.4 *Embelga* irrigation



Source: Carvalho 1994 (slightly adapted)
Note:
- In the uneven turns the order of irrigation of the *embelgas* is against the flow direction, in the even turns the order is in the direction of the scheme flow. In this way, when in one irrigation turn the last *embelga*s receive less water because irrigation time for the plot has already finished, the next irrigation turn will irrigate these *embelgas* first. This alternation of irrigation sequences results also in saving on labour input because the checks (of earth, made by hoe) in the field canals and entry canals of the *embelgas* necessary to irrigate in the second order already have been made in the first order while the checks removed in the 2nd turn le ft the field prepared to start the irrigation of the 3th turn.

Performance of irrigation methods
A local research project (Rego *et al*. 1990; Thies 1989) made an evaluation of traditional methods of irrigation used by farmers. The most important findings of this study are related to the efficiency of water use. The evaluation of the efficiency of irrigation was based on 3 indicators defined by Merriam *et al*. (1983):

- Application efficiency (AE): ratio of the water infiltrated and stored in the root zone (in depth or volume) to the total water applied (in depth or volume), expressed as a per centage.
- Uniformity Coefficient of Christiansen (UC) : ratio of the average depth of water infiltrated minus the average deviation from this depth divided by the average depth infiltrated, expressed as a percentage.

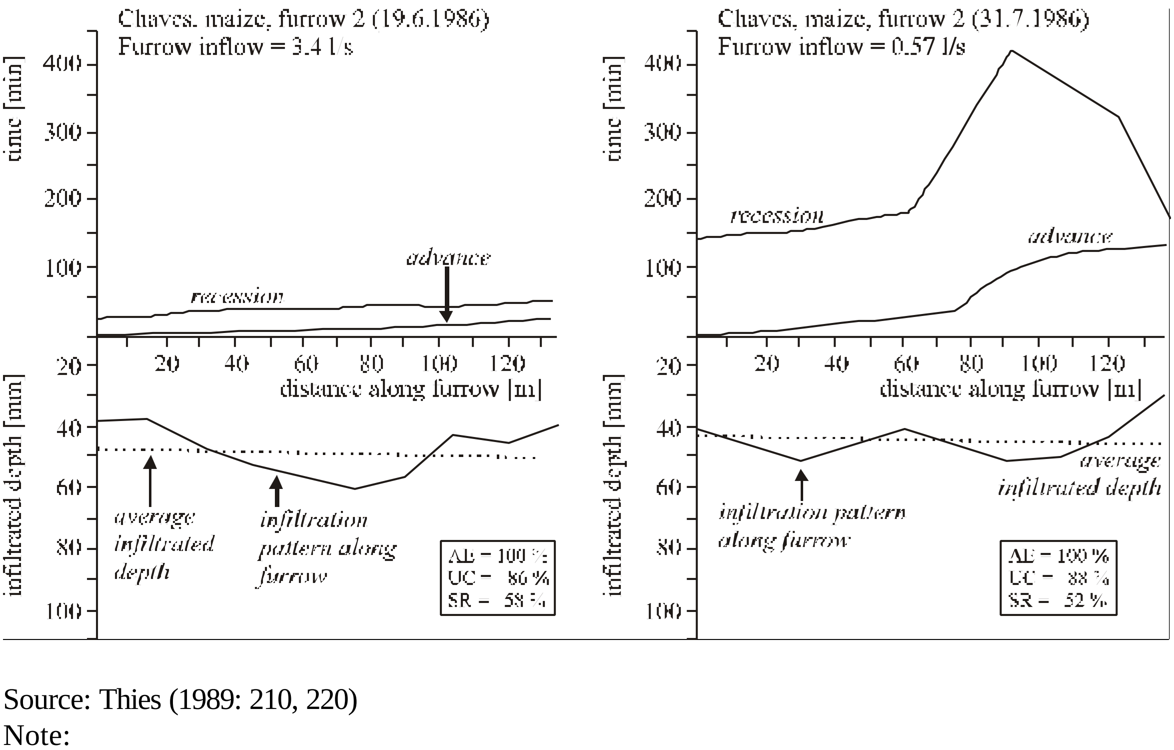
- Storage Efficiency or Storage ratio (SR): ratio of the average depth of water stored in the rootzone to the average depth storable, expressed as a percentage.

An analysis of this efficiencies shows that:

- Application efficiencies (AE) are mostly near 100 per cent, i.e. there are hardly water losses caused by runoff and deep infiltration outside the rootzone. This shows that farmers are very aware of the scarcity of water.
- The uniformity of water application (UC) is generally high (about 80-90 per cent) but varies with the length of furrows. For short and blocked furrows this uniformity is particularly high
- Storage efficiencies (SR) are variable. They tend to be low in short furrows and borders with a low infiltration rate but are increasing considerably with a increasing length of the furrows and higher infiltration rates of the borders.

These findings are illustrated in Figures 2.5 and 2.6 for a furrow with maize and a furrow with potato, respectively. To improve the distribution of infiltrated water over the furrow, sometimes, principally in furrows with steeper slopes, some intermediate checks are constructed (see Figure 2.7) against the direction of flow, after water has reached the end check.

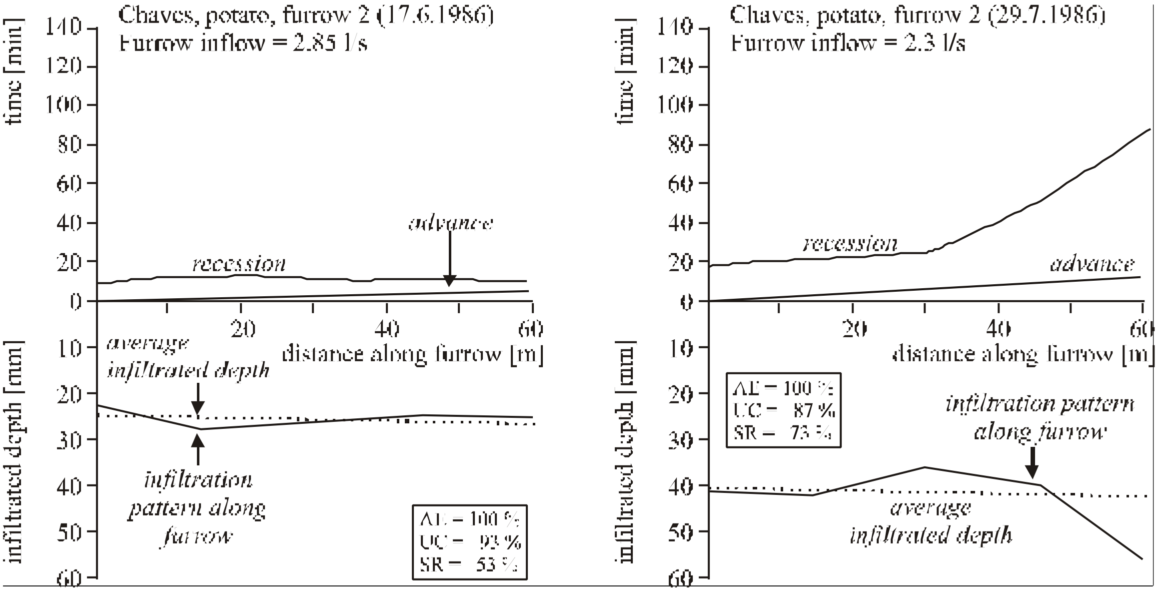
Figure 2.5 Infiltration patterns in a maize furrow



Source: Thies (1989: 210, 220)
Note:
- the figure representing the irrigation at 31.7.1986 shows approximately the same infiltration depths at the end of the furrow as at the beginning of the furrow while opportunity times (the time that water is infiltrating, equal to the difference between recession and advance times) are very different. The

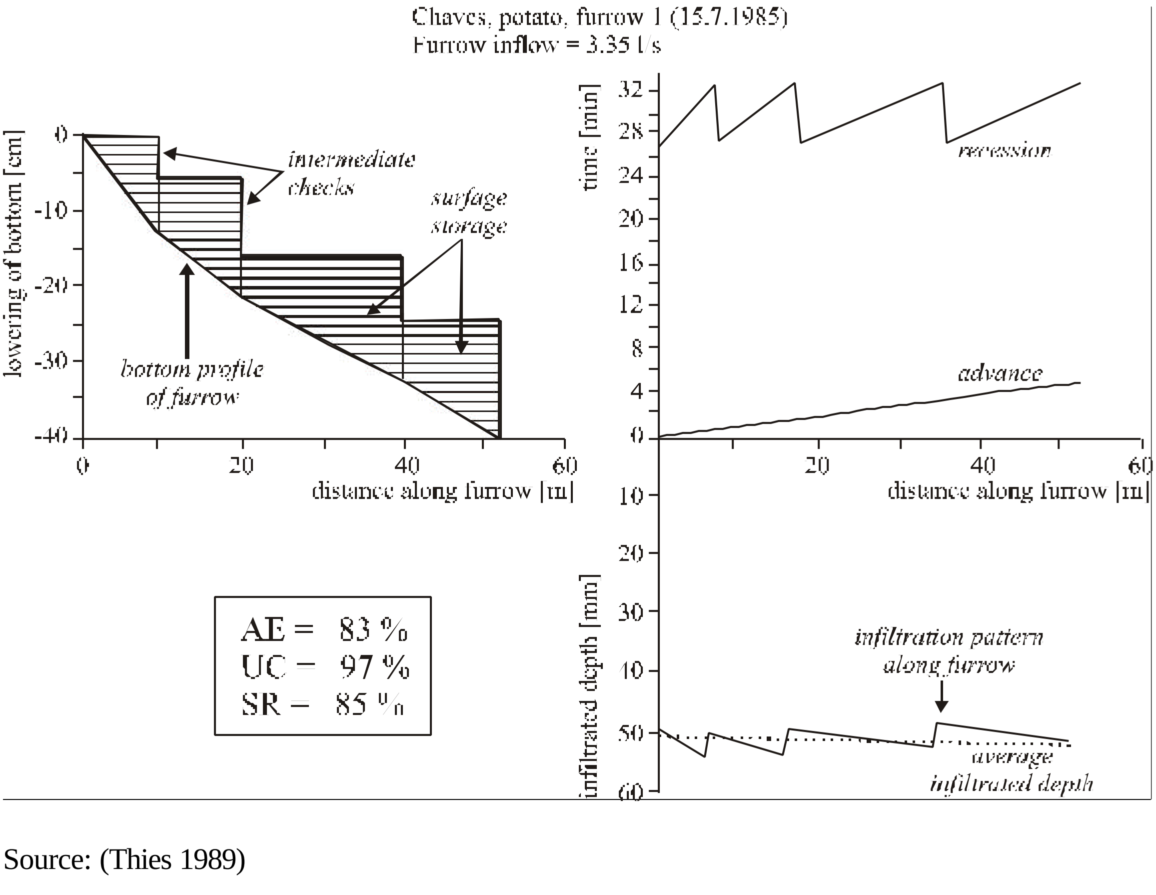
explanation lies in the movement of fine soil particles during the irrigation season to the end of the furrow, resulting in a layer of lower permeability (Thies 1989: 34, 56).

Figure 2.6 Infiltration patterns in a potato furrow



Source: Thies (1989: 225, 232)

Figure 2.7 Distribution of infiltrated water over a furrow with intermediate checks



Source: (Thies 1989)

Notes:
- with intermediate checks a more regular infiltration pattern along the furrow can be realised (UC = 97 per cent)
- more checks allow for a higher infiltrated depth
- this method requires more labour input per ha but not necessarily per m^3 applied water

These findings show that farmer's field irrigation methods are very well adapted to field conditions in Trás-os-Montes taken in account the small and variable flows, the small plots and the variability of slopes[31]. These findings also contradict the so widely spread belief in engineer's and water management circles that these surface irrigation methods are by definition inefficient[32], i.e. involve much application losses. At the other hand, the very high application efficiencies point to low irrigation application depths. In itself this is a sound practice but in combination with long irrigation intervals (in some systems up to 30 days) it results in underirrigation. In that case irrigation has been insufficient to supply full crop water requirements and consequently result in lower than potential or maximum crop yields, assumed that water is the limiting factor in crop production. On the other hand, it can also work the other way around: a long interval will stimulate the irrigation of particular crops that are less sensible to water stress, for instance meadows.

The lower yields as a consequence of underirrigation do not imply definitely a lower total production than the one that potentially could be achieved by the application of the given quantity of scarce irrigation water. When yield is related to the total applied irrigation depth then the resulting curve normally has a convex form as has been shown by many experiments (Stegman *et al*. 1983). That means that the crop yield response to incremental irrigation inputs is subject to the principle of diminishing marginal productivity, *ceterus paribus* (all other conditions equal). That is, field application losses (run-off, deep percolation, residual extractable water or extractable water left over after harvest) will increase more than proportional as water is applied to achieve maximum evapotranspiration and crop yields. So, it can be concluded that within certain limits, irrigation water spread over a larger area implying underirrigation has a higher irrigation water use efficiency (production/m^3 of applied irrigation water) than irrigation aimed at maximum yield. Moreover, rainfall is used more efficiently. In most Trás-os-Montes systems, irrigation water availability in the summer is scarce in relation to land. Farmers have an incentive to use water efficiently which will be translated into the maximisation of agricultural production per unit of water (as shown by the phenomenon of underirrigation) instead of maximising yields[33]. This is the opposite of the 'normal' systems, which are designed by engineers to cover full crop water requirements for maximum yields.

The high labour input is a highly important characteristic of summer irrigation practices. Factors that contribute to the high labour input in irrigation are various. First and foremost, the largest part of labour input in irrigation is the water application at field level (the time that farmers are in fact irrigating) because flow rates are generally very restricted in the summer. Low flow rates imply a very intensive labour input (10-80 hours/ha for one irrigation turn depending on available field flow rates and irrigation depths). Table 2.4 indicates the required labour input in field irrigation within the ranges of irrigation depths and field flow rates which normally occur in the irrigation systems of Trás-os-Montes.

Table 2.4 Required labour input (hours/ha) in field irrigation in dependence of irrigation application depths (mm) and field flow rates (l/s)

Application depth *M^3/ha* *mm*		*250* *25*	*300* *30*	*400* *40*	*500* *50*	*800* *80*
Field flow rate *l/sec*	 *m^3/h*	*hrs/ ha*	*hrs/ ha*	*hrs/ ha*	*hrs/ ha*	*hrs/ ha*
2	7.2	34.7	41.7	55.6	69.4	111.1
3	10.8	23.1	27.8	37.0	46.3	74.1
4	14.4	17.4	20.8	27.8	34.7	55.6
5	18	13.9	16.7	22.2	27.8	44.4
6	21.6	11.6	13.9	18.5	23.2	37.0
8	28.8	8.7	10.4	13.9	17.4	27.8
10	36	6.9	8.3	11.1	13.9	22.2
15	54	4.6	5.6	7.4	9.3	14.8
20	72	3.5	4.2	5.6	6.9	11.1
30	108	2.3	2.8	3.7	4.7	7.4

Notes:

- Application depth [m^3/ha]= flow rate [m^3/hour]* application time [hours/ha]
- Application depths < 25 mm are not considered because it is hardly possible to apply these small depths in an efficient and uniform way with surface irrigation methods.
- Although many sources have a flow less than 2 l/s, these small flows are normally not directly used in field irrigation but first stored in reservoirs. When the accumulated water is released, the outflow rate is increased in relation to the original source flow.
- The table is made with the assumption that one person is able to handle the incoming flow rate and to irrigate the plot. Particularly at relatively high flow rates (>10-15 l/s) mostly 2 persons are needed to irrigate efficiently i.e. without losses. Even at smaller flow rates, the irrigator needs help in some situations, e.g. someone to indicate when the water stream is coming to the end of a furrow in case this is not visible because the crop has already covered the soil.
- Flow rates and application times are in a high degree determined by the irrigation system because they depend on water source flows and the duration of the periods determined by the type of water rights and the water allocation system (see section 2...). Water application depths can to a certain degree -dependent on infiltration characteristics of the soil- be regulated by the choice of area size.
- The table is only valid for the field irrigation of summer crops. Meadows are irrigated by the method of overflowing field ditches. Intensive guiding of the water and permanent attention is not required in this irrigation method.

Second, the scattering of plots leads to a dispersion of irrigation turns. Therefore irrigation activities are also frequent, dispersed, rigid[34] and labour-demanding. To the time needed to irrigate must be added the time necessary to walk between farmstead, water sources, reservoirs and plots. In many cases also much time is needed for routine maintenance of the irrigation canal and to conduct the water from the source or reservoir to one’s plot, principally in case of small flows. Moreover, most irrigation activities occur at the peak time of the agricultural season when many farming activities need to be executed. Third, in some cases additional labour is needed for patrolling water source and irrigation channel to prevent water theft.

Fourth, in the case that night irrigation is practised, it is a heavy, drudgerous task with many inconvenients as shows the following comment of an irrigator of Vila Grande in 1990, referring to the situation before MRT-intervention (quoted in Portela 1990):

> *'here we irrigated the whole night with a candle. We had to guard the water during the night to avoid that others below the village of Cerdedo would rob it. It was like that….a permanent tension. Irrigating at night is very difficult and annoying. We became all wetted with the fog and we had pain because of rheumatism. It was harder than the harvest (of rye)'*

When they are alone, irrigators have difficulties to light their work (some hold a sack lamp in their mouth) which prejudices the quality of field irrigation. Women alone will not irrigate at night because they should not leave home at that time according to the reigning social conventions/customs.

Winter vs. summer irrigation

The importance of the 'winter' irrigation of hay meadows (*lameiros*) for many farmers, especially in the mountains, is reflected in the large share of these meadows amounting to 2/3 of total irrigated area (see Table 2.2). The irrigation of hay meadows has different characteristics compared with the summer irrigation of food crops, as is shown in Table 2.5.

In general, winter irrigation of *lameiros* didn't take place on the summer irrigation areas. However, in quite a lot of villages with specific farming systems and scarce labour resources, this is changing because of a clear tendency to transform irrigated arable plots into permanent meadows[35]. Normally, winter irrigation perimeters are located more upstream and/or more downstream (less frequently) of the summer areas and along nearly all permanent and temporary surface streams. Meadow areas can be found frequently on steep to very steep slopes (>30 per cent) with thin soils which are less terraced than the summer areas. The use of these sloping lands as meadows constitutes both a productive and an ecologically sound practice which minimises erosion hazards (Raposo 1996; Azevedo 1990). Use of irrigation infrastructure by (small) groups of farmers (*consortes*) are predominant. The nature of permanent meadow (*lameiro*) irrigation is diametrically opposed to that of food crops in the summer. Irrigation of food crops is labour intensive and field application aims at using the small quantities of water at the most efficient manner. Irrigation of meadows is labour-extensive, irrigation canals and field irrigation method (called *rega de lima*: a variant of contour ditch irrigation in which water is diverted from a contour ditch and is let to flow down the natural slope) are suitable respectively to transport and to spread large quantities of water. To realise good water circulation within the *lameiros*, a more or less dense network of field channels needs to be constructed. If the plots are prepared in this way, farmer's presence is not required for irrigation of the *lameiros* (see Box 2.9). As part of this labour saving technology an ingenious artefact is used generally in Trás-os-Montes, called *pedra de engenho* (see Box 2.10).This is a self-starting siphon built in a reservoir. Once the reservoir is full and the incoming streamflow is relatively large (in the winter period) the siphon will be activated and will empty the whole reservoir within a short time. It is a type of automatic irrigation fully adapted to the winter irrigation of meadows (large streamflows). In the summer the siphon cannot be activated because the incoming streamflow is too low. In this period the reservoir needs to be opened by hand and the outgoing streamflow will be carefully regulated to optimise the use of the small quantities of available water.

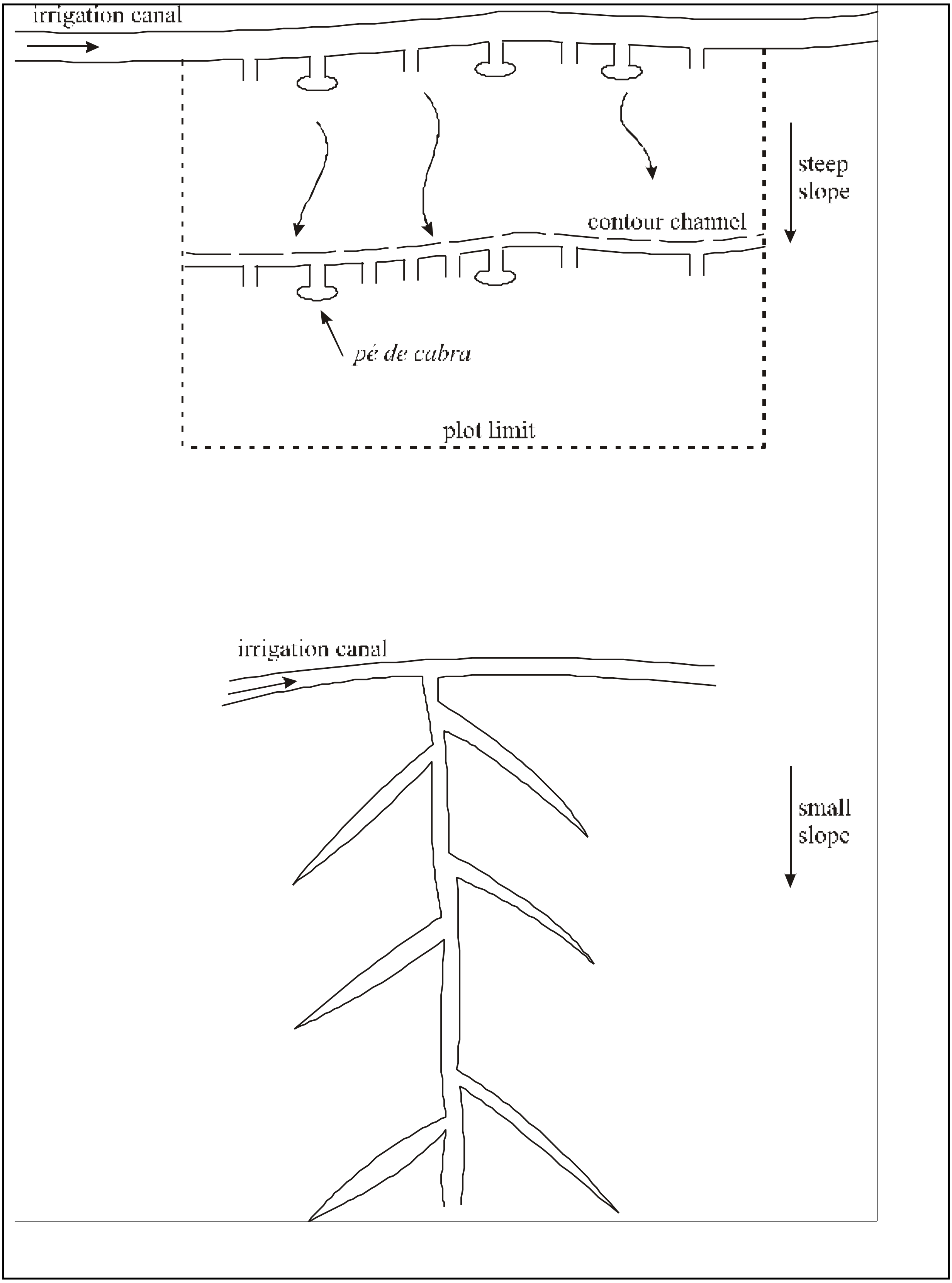
Table 2.5. Comparison between winter irrigation of *lameiros* and summer crop irrigation

Characteristics	*Winter or 'lameiro' irrigation*	*Summer crop irrigation*
1 irrigation period	1 October-June (the end of period is rigidly fixed in many mountain schemes)	1 July-September (before this period, irrigation is hardly necessary)
2 objective(s)/goals	2 * protects against frost (in winter) * grass growth (March-June) * manuring value	2 water requirements of food crops
3 available water	3 hardly scarce	3 increasing scarcity in the summer period
4 preferential sources	4 * springs (higher temp. in winter) * streams (high flows)	4 most productive and constant sources (springs, streams)
5 nature of irrigation	5 continuous flow	5 intermittent
6 field irrigation method	6 overflowing contour ditches ('wild flooding')	6 short furrow/ controlled flow irrigation ('*embelga*')
7 channel losses	7 not relevant	7 depend of channel and improvements (lining)
8 field application efficiency	8 not relevant	8 near 100 per cent (underirrigation)
9 labour input	9 minimal	9 intensive and drudgerous
10 property regime of irrigation facilities	10 small groups ('consortes'), individual	10 the majority of farmers are co-owners of comunal systems and/or group systems (*consortes, herdeiros*) and/or, individual facilities
11 access to water/ water rights	11 free, minimal rules (except for water mills)	11 in communal systems mostly well-defined in quantity and periodicity, in group systems somewhat looser rules

Box 2.9 Winter Irrigation of Permanent Meadows

According to Gonçalves (1985) the most important objective of the winter irrigation of permanent meadows or *rega de lima* is to diminish and remedy the harmful effects of frosts. The practice of the *rega de lima* is aimed at covering the meadow constantly with a small layer of slowly moving water. The irrigation water, principally during the night, is relatively warmer than the soil, the meadow and the surrounding air and thus gives off big quantities of warmth, restricting cooling. Moreover, the water covers the soil and part of the plants, in this way diminishing much the outgoing radiation of the soil during the night.

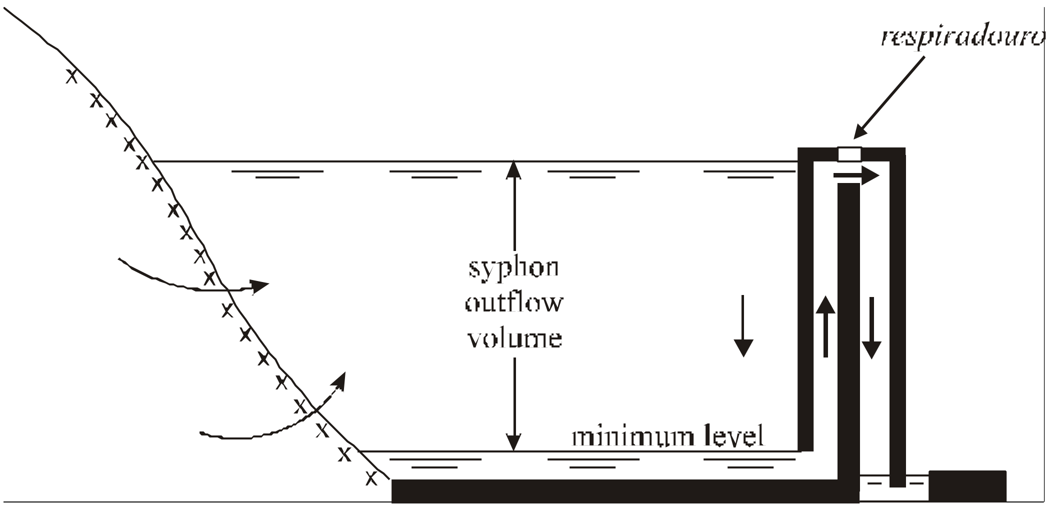
Ideally from a contour channel on top of the meadow, irrigation water will overflow uniformly over its whole length and spread out over the meadow. Some distance along the slope the excess water that did not infiltrate will be collected in another contour channel and the same process of overflowing and spreading will repeat. This ideal situation supposes a very regular slope and topography. In practice topography and slopes are more irregular. Dependent on the degree of irregularity a more dense and elaborated lay-out of additional distribution furrows (*tralhas* or *tralhões*) taking off from the contour channels is needed to distribute the water uniformly in order to avoid both dry and too wet spots. With a large streamflow all the *tralhas* receive water at the same time, the presence of an irrigator is not needed. When the streamflow is smaller, an irrigator need to distribute the water over the '*tralhas*' sequentially. Complex and intricate forms, e.g. T-forms (*pé de cabra*) in very steep fields (Strijker 1992) can be observed. In other cases the furrows have fish-bone configurations etc. This type of irrigation is an outstanding example of skill-oriented technology: Instruments are very simple (a hoe) but a very precise knowledge of the land and water flows are needed for the lay-out of the furrows in the field.


irrigation canal
steep
slope
contour channel
pé de cabra
plot limit
irrigation canal
small
slope

Box 2.10 Pedra de Engenho

The *pedra de engenho* (literally: stone of ingenuity) is a self-starting siphon constituted by a closed conduit in the form of an inverted U with an inlet, upstream leg, throat, downstream leg and an outlet (see Figure below), fixed on the wall of a reservoir of brick/concrete (*tanque*) or soil (*poça*). There exist many materials and ways to construct this siphon. The oldest form consist of granite stone elements. Normally the throat is formed by a simple cover stone which has a small orifice (*respiradouro*) which can be opened or closed with a small plug. In order to work as a siphon the *pedra de engenho* must be closed hermetically. To this end the plug has to be put into the *respiradouro*. Mud will be used to close the hole air-tight. The *pedra de engenho* is widely used in the mountainous areas of the Trás-os-Montes, Minho (Northwest Portugal) and Galicia (Spain) regions and is still constructed by local craftsmen (Morgado 1993; Dias 1986). Besides granite stone, nowadays the most variable materials are used to construct these structures such as concrete, bricks (Barroso), plastic and PVC tubes (Serra de Alvão, Vila Real), wood (Minho).

The *pedra de engenho* can function as a siphon when the *respiradouro* is closed air-tight. Once the reservoir is full, the water will flow over the throat to the downstream leg. If this flow is considerable (such as in winter and spring), the siphon will be primed: the air in the lower leg will be taken away with the outflowing water so that a vacuum is created and the reservoir will empty rapidly. When the water level in the reservoir drops below the inlet of the upstream leg, air will enter and flow will abruptly end. When the flow is low (as in the summer) the siphon cannot function automatically. Normally, the wall of the reservoir is equipped with a simple orifice which will be closed (with wood plugs or old clothes and mud) or opened according to the desired outflow.



General features of FMIS in Trás-os-Montes

From the analysis of data on the systems researched here some general and interrelated features relating to the construction and management of FMIS can be deduced:

- *Rudimentary irrigation facilities*. A typical gravity scheme consists of a simple (temporary)diversion structure at the water source(s), earthen canal(s) or carved out in rock and in most cases storage reservoir(s), which are unlined or only partially lined. At the water intake from rivers there are hardly any structures to limit the amount of water which enters the canal in the winter. Excess water is simply drained by overtopping of the canals. Also water distribution structures are absent. Industrial construction materials like cement etc. are sparsely applied except in the PDRITM intervened systems.

- *Simplicity of operation*. Normally, (summer) water flows are not divided[36]. Every farmer uses the whole flow in the system when it is his/her turn. During that period (s)he is the only operator of the irrigation system, from source to field. When water will be stored in a reservoir (s)he needs to close and open it in due time. Note that these operational features imply low transaction costs (in monitoring) and are interrelated to the absence of distribution structures (infrastucture) and the low water flows in the summer (physical characteristic). Rules, artefacts, technology and nature are 'in line'. At the contrary of the summer period, in the winter, dividing of (large) water flows and simultaneously irrigation of more plots is quite common.

- *Few head-tail problems*. Many farmers have plots scattered throughout the irrigable area, which reduces the tensions within this area. This is not the result of working rules[37] but is a consequence of the ongoing division of plots with different ecological properties because of inheritance, marriage, purchase and selling of land etc.

- *Minimal collective resource mobilisation for operation and maintenance*. The operation of the system is usually very clear because of the strict allocation and distribution of the irrigation water (see Chapter 2.4). The maintenance or reproduction of the system is not a critical activity[38], which represents a contrast with FMIS in other mountain areas over the world[39]. It is limited to the reparation of weirs, reservoirs and canals, frequently deteriorated or destroyed by the heavy rains in the winter. Normally, to keep up the right over water (Coward 1986) all water users are expected to participate in the collective maintenance of scheme facilities during one day before the summer irrigation starts, independent of the share of irrigation water they have right to. In some villages (e.g. Pincães) even the participation of village habitants without water rights was required because water is also used for e.g. fire combat. This equal-contribution rule, which implies an incongruence between costs and benefits (equal labour contributions but different water rights) is only applied in maintenance activities. In improvement activities and very probably also in the original construction of the FMIS in Trás-os-Montes the proportional rule (costs in proportion to benefits, see Design Principle 2 in Box 1.1) is generally applied.

  Contrary to these minimal collective efforts, a lot of labour is needed for operation, routine maintenance, field irrigation and sometimes source and canal patrolling in order to prevent water theft. The intensity of these activities depends much on the location of the irrigated field: it costs much more labor to irrigate a field in the tail end than in the head end.

- *Low transaction costs,* that is the costs of coordination, monitoring and enforcing the working rules underlying the functioning of the system. The equal-contribution rule in maintenance is a clear example of low transaction costs[40]. This rule permits to notice easily the physical presence and absence of members on this collective maintenance day and so to restrict free riding[41]. That type of physical control of communal labour is easier than the control of (invisible) money contributions that can be easily used for private purposes if accounting mecanisms are not in place. That is an important reason why relations within many FMIS are hardly monetised[42]. That is not to say that applying the rules, even with minimum transaction costs, is without any problem. Take for instance the equal-contribution rule. This rule could be formulated, for instance, as: 'each household must send one person for one day to help in the cleaning of the irrigation canals'. Even such a simple rule is more complex than it seems at first sight. It can be interpreted quite differently by different people. To cite Ostrom (1990:100, 101):

'Who is or not a 'person' according to this rule? Does sending a child below age 10 or an adult above age 70 to do heavy physical work meet this rule? Is working for four hours or six hours a 'day' of work? Does cleaning the canal bordering one's own farmland qualify for this community obligation? People can 'interpret' a rule so that they argue they have complied with the rule, but in effect subverting its intent. Even individuals who intend to follow the spirit of a rule can make errors. What happens if someone forgets about a labour day and does not show up. Or what happens if the only able-bodied worker is sick, or unavoidably in another location. Should some households be allowed to free-ride by sending less able persons than others will try to do the same. If this continues for a long time, only children and old people would be sent to do work that would require adults, and the system would break down. If mechanisms to resolve conflicts are not in place, it is difficult to imagine how any complex system of rules could be maintained over time'.

A main characteristic of the majority of the conflicts occurring in Trás-os-Montes systems is that they are considered just a matter of the parties involved. If these conflicts cannot be resolved, sometimes a (formal) organisation like the Parish Council (*Junta de Freguesia)* is able to mediate. There is a limited number of cases involving legal action and hiring of lawyers. But for juridical structures it is difficult to resolve these problems because they are highly contextual and often water rights are not explicitly written down. In Santa Marta de Alvão the court said it was unable to judge over such matters (Bleumink *et al*. 1992:45). In the case of Pincães a process led to the official registration of water rights. In the case of court cases power relations and money (costs of advocates) eventually seem of decisive importance. There are many types of conflict but most are centred around the – real or supposed – theft of water which manifests itself on various ways e.g. closing the reservoir before one's time share starts, robbery of water during the night, division of flows (Prins 1991: 61) etc.

- *Absence of formal water users organisations*. The driving force behind the daily functioning of the systems is the own interest of the individual water users to obtain the water they are entitled to. This is self-evident and leads to a nearly automatic control and enforcement of the rules. In some systems the irrigators appointed officials to whom are assigned the functions of coordination, monitoring and enforcement[43]. The importance of local government organisations like the Parish Council[44], local leaders, (interest) groups etc. comes to the surface at important tactical and/or strategic moments, for instance to fix the beginning of the summer period or to decide on the future of the system, e.g. improvement of scheme facilities, changes in water allocation and/or distribution rules. For instance, in many cases it is the *Junta de Freguesia* that formulates or supports the request for an MRT intervention.

Besides these shared design and management features, every scheme has emerged and developed in specific historical and local circumstances that have led to a large diversity in physical systems and functioning of FMIS.

2.4 Diversity of farmer-managed irrigation systems: key elements

The diversity found among the irrigation systems is related to the very reason of existence of irrigation, namely the delivery of water to farms for agricultural production. In conventional irrigation engineering this is self-evident. What else is irrigation than the alleviation of crop water deficits? So, water delivery based on the water requirements of crops is the logical outcome (Diemer and Slabbers 1992: 6). In this approach water delivery is reduced to a technical question, that is how to find an optimal technical solution. However, there are many potential solutions, also depending on the context in which irrigation takes place. The aforementioned paradigm abstracts from the social dimensions of water use[45]. It hides the key problem of any irrigation system, namely *the control over the use and access to a scarce resource as irrigation water*. The dimensioning and functioning of FMIS in Trás-os-Montes is not based on 'neutral' technical criteria regarding the water requirements of crops. With this statement I don't mean to suggest that crop water requirements are irrelevant, on the contrary. When irrigating their fields, farmers evidently take into account the quantity of water that crops need to produce and look for ways to maximise the use of the expected available water on their fields. That is reflected for instance in the type of crops, cropping patterns (the distribution of crops in time and space), planting dates and cropped areas, presenting knowledge that is the product of many years of observation and experience. But on system level it is *the sharing of a scarce resource* that explains the logic (or design principles in terms of Ostrom) behind the functioning of the systems. However, within this logic and depending on the socio-economic and physical context in which the irrigation systems are embedded, they operate in quite diverse ways.

An analysis of the data of the communal systems studied shows that the diversity of functioning of FMIS is clearly related to three strategic interrelated key elements in the schemes: water availability, water allocation and water distribution. *Water availability* is a good measure of the productive potential of the communal water source(s). It varies during the agrarian calendar. *Allocation* means the assignment of rights of access to water among users (Martin *et al.* 1988a). This very general definition points to two main aspects- a qualitative aspect: who may and who may not use the water, and a quantitative aspect: to what share or part of the available water or the actual water flow a right holder is entitled. However, the shares can be defined on different grounds or principles. Under some principles the shares are loosely or not defined, under other principles the shares are defined in detail in terms of when and/or where and/or how much. This will be discussed later on in this chapter. Different rules may be adapted for water allocation in different periods of the agrarian calendar (e.g. summer vs. winter irrigation). The diversity in the functioning of FMIS manifests itself in a scheme specific water allocation, developed on the basis of obtained water rights by the water users.

But the division of shares or rights among users must be converted into real water flows. This real water flow pattern in which water is divided in time and space amongst users, i.e. the physical distribution of water among users (Martin *et al*. 1987) is called *water distribution*[46]. It is the materialisation of abstract water rights in flows to the fields, it refers to how, when and how much water is delivered to the fields according to the assigned water rights. On the other hand, the precise definition of farmer's water allocation only makes sense if the system can in fact deliver to each farmer the share of supply to which he is entitled (Martin *et al*. 1988). For instance, in some situations the outflow pattern of reservoirs is more difficult to fit in with or to harmonise with certain allocation principles. I will come back to this question in Chapter 7.3. The translation of water allocation into distribution is further shaped by interpersonal arrangements between rightholders, e.g. exchanges of water turns. The essential of good irrigation management is to distribute water according to the allocation arrangements. In the translation from abstract rights into delivered water to farmer's fields many practical questions need to be addressed, to name only one thing how to distribute night irrigation between the water right holders. There are different ways of doing this and it will differ from system to system (see the section on water distribution in this chapter and for a case study, see Chapter 3.2). It shows that the relation between water allocation and water distribution is not deterministic. Water availability, allocation and distribution are interrelated through the distribution infrastructure, the water distribution rules and the interpersonal arrangements which shape the translation of water rights into real water flows. Figure 2.8 is an attempt to schematise these interrelations.

Figure 2.8 indicates that these interrelationships in the FMIS are not fixed but highly flexible during the agrarian calendar. When the balance between water availability and water needs i.e. the resulting water scarcity changes -dependent on the climatic season and planted or sown crops- then allocation (principles), the use of infrastructure, the distribution rules and the resultant water distribution also change. Rigidity and flexibility of water allocation and distribution are directly related to the available water supply. In winter and spring when water availability is high, allocation and distribution of water is much less rigid (although there are exceptions) than in the summer when water is scarce.

Figure 2.8 Interrelationships between elements that shape water distribution

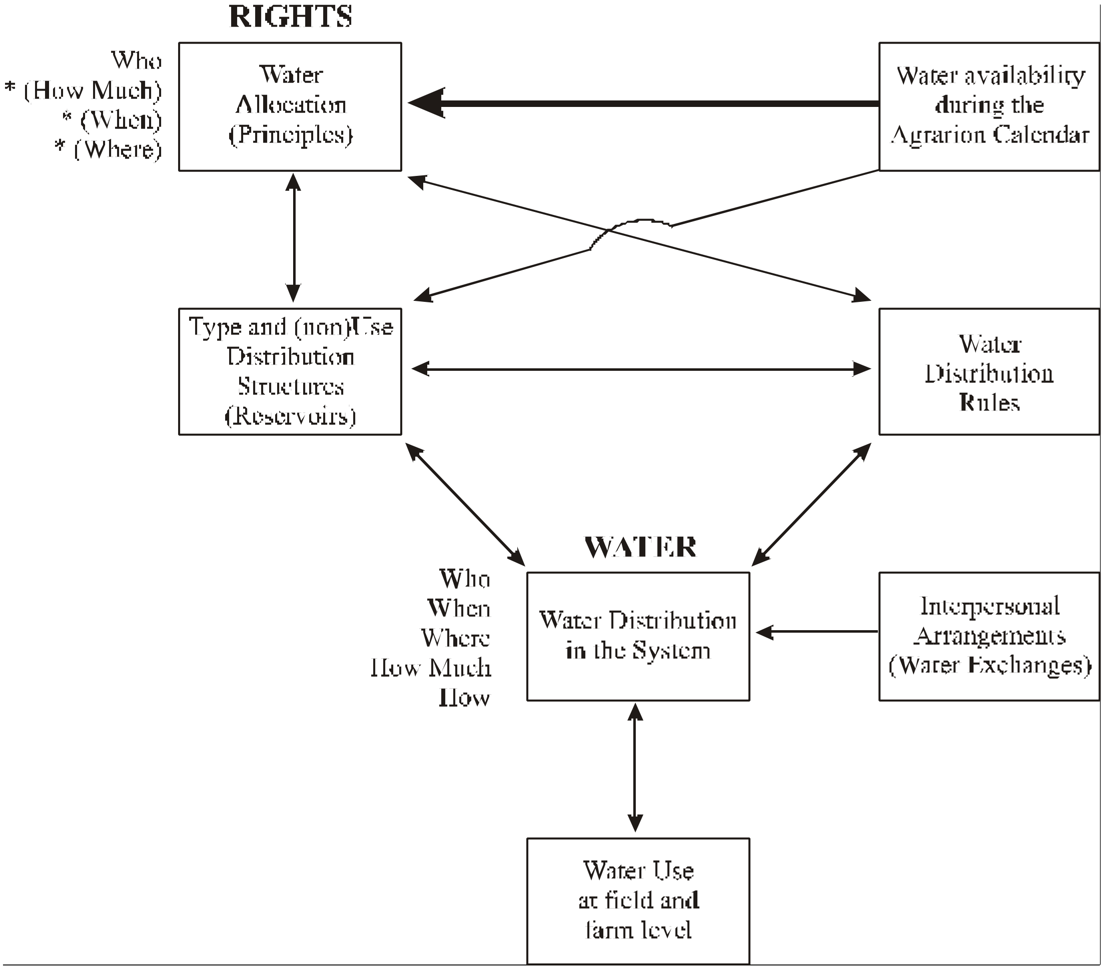


Figure 2.8 shows also that changes in the above-mentioned parameters, for instance by interventions, could affect the other ones. These interactions will be further discussed in this chapter on the paragraph dealing with water distribution and the Chapters 6 and 7.

Water allocation

The origin of the water rights in Trás-os-Montes is no longer remembered. In most villages people responded that the irrigation system has always been there, and that water rights were traditionally defined. Not one case has been encountered where people remembered the system's origin. Water rights are stored in the collective memory of the village community and passed from generation to generation[47]. In a few villages the water allocation is explicitly written down[48]. In these villages a *rol* (order of turns) exists, which is functional in times of water scarcity i.e. during the summer months. One may hypothesise that one's water rights were acquired proportionally to one's investment (labour, location of water source and irrigation channels, right of way etc.) in facilitating irrigation (physical infrastructure), as has been proved in many other situations[49]. However, empirical and historical evidence for this has not yet been found.

Known history shows that over time, water rights in all systems have gone through significant changes. The actual number of water rights has increased considerably compared to the original number. In most villages, original water rights were large shares in the hands of a limited number of families and linked to certain areas. These large shares fragmented into smaller portions through sale and inheritance practices, parallel to the division of land. Later, transactions of land and/or water shares, marriage and negotiations have created diverse patterns of allocation.

A unique and very important feature of the water allocation in most Trás-os-Montes systems is the distinction between winter and summer irrigation rights. In the winter water rights have been and in some systems are still concentrated in the hands of a smaller group than in the summer. This group is constituted by cattle breeders: for this group winter irrigation of the *lameiros* is one of the pillars on which their farming system is constructed.

Principles of water allocation

The studies of the communal irrigation systems have revealed that water rights may be defined on different grounds. Shares may be expressed in time, or in surface area to be irrigated, or may not be clearly expressed at all.

These bases for the definition of water rights I have called the *water allocation principles*. They provide grounds for the qualitative and quantitative assignment of water to right holders. The four main principles of allocation in Trás-os-Montes are detailed below (for the summer water allocation in the sample of 28 villages, see Table 2.6[50]).

1. Time-based: time shares

The allocation principle that is most frequently met is the division in time shares. A fixed irrigation interval is divided into a number of time shares. During the period of a share the water user is entitled to use the entire flow. When water is first stored in a reservoir (*poça*), the time share corresponds to the accumulated flow during that time. The duration of the time shares may vary; they range from several minutes to more than one day. The number of time shares per water user differs as well. These two factors result in major inequalities between the users' access to water, at least at system level.

Where time shares are applied, water is allocated to individual water users. The right to water is considered a person's private property to be used in whatever way (using, selling, leasing etc.) (s)he wishes. However, in most systems the implementation of the time shares (water distribution) is linked to particular plots as well. The freedom to use the time share in whatever way is restricted by the physical location of the plots. At the moment the flow reaches the entrance of a plot, the period of time of that plot's share starts to count. During this period the water may be applied to this plot, and to other plots as well. The only restriction is that the flow must be passed on to the next person at the entrance of his plot when the time of the share is over. Only in systems with storage facilities a person may combine his time shares to use them in one single turn.

2. Time-based: equal time shares

Irrigation water is not linked directly to people, but is considered a local common property. Division of the water is proportional to the number of social units; households, in most villages, that claim rights to its use. Each social unit is entitled to the entire flow for a fixed continuous[51] period of time, which is the same for each unit. This time share varies per year, dependent on the number of social units in a certain year.

The right to the water usually depends on residency in the village. To convert this claim into a one year's water right, an inhabitant must participate in the maintenance of the system and/or contribute to other common interests like road repair, church cleaning or the supply of fuelwood to the communal oven. As a consequence, people who have emigrated lose their water rights but upon their return to the village they may again claim water. Even landless villagers are entitled to an equal share, which they may sell, or use in share cropping.

This type of allocation is equal in theory, but may be subject to abuse in practice. In some villages it became evident that households with more resources sent more than one person to the maintenance activities to obtain multiple water rights. An old woman remarked that some people receive almost all the water because they send hired labourers, while she herself receives hardly any water because she can afford only one day's labour.

3. Plot-based

The owner of a plot is entitled to use the entire system flow until his plot is irrigated sufficiently. 'Sufficiently', in these cases, is socially defined: a water user may not waste water or continue to irrigate indefinitely, arguing that the plot still needs water. General practice is to stop irrigation when water has covered the whole plot. This doesn't allow for a large infiltration time, and consequently implies small irrigation applications. As already mentioned in Chapter 1, I have observed irrigators who were helping their neighbours in order to irrigate more rapidly[52]. Water is bound to a certain fixed area, irrigation turns follow a fixed order and contiguous plots are successively irrigated.

This type of water allocation developed from inheritance processes in which heirs divided the land but did not divide irrigation time accordingly. A variant is the division of a plot with associated irrigation source (well, spring) and/or reservoir which are indivisible. In this way emerged the *poços de família* (family wells) and *poços de grupo* (group wells) (Bernardo 1983).

Table 2.6.Summary of water allocation and water availability in the communal systems of 28 selected villages

Village (For location, see Fig 2.2)	*Water Alloc. (1)*	*Water Avail. (2)*	*Agro-Ecolog. Zones (3)*	*PDRITM Inter-Vention:*	*Remarks/Interventions in system by water users (indicated here only the most important)*
1. Corva	1.	++++	M	1992	Conflict with Neighbouring Village
2. Sesmil		+	HV	1983	Change in W. Rights (1983-85)
4. Lamas d'Olo		+	M	1990	
5. Covas		+	HV		
7. Seixedo		+	HV		Improvement by Water users
8. Tresmundes		+	HV		
9. Sobradela		+	HV		Improvement by Community
10. Sta. Marta da A.		+++	M	1989	
15. Fervidelas		+++	M	1992	
16. Adaes		+	HV		
18. Vilela		+	HV		Improvement by Water users
19. Sta Marta		+	HV		
20. Aboboleiro		++	HV		Upstream of Bouca (06)
21. Bosto Frio		++++	M		Improvement by Community
27. Brito de Lomba		++	HV	1991	
28. Roriz		++	HV	1990	Change in Waterall. type 2 to 1
11. Meixedo	2.	+	M		'92 Change in Water all. type 5 to 2
12. Torgueda		+++	M		‘90 Change in Water all. type 5 to 2 + Improvement by Community
25. Cimo de Vila de Castanheiro.		+	HV		
26. Vilar de Lomba		++	HV		’75 Change in Water all. Type 1 to 2
17. Santiago	3.	+	HV	1987	Discussion Water all. Type 3 to 1
24. Vilalva	4.	++	HV	1991	Discussion Water all. Type 4 to 1
6. Bouca	5.	+	HV		Dependent on the same river as (20)
22. Soutelo		+	HV		Past Change in Water all. type 1 to 5
	6.				
3. Vila Cova	TT	+++	M	1986	
13. Romainho	5L	+++++	M	1989	Discussion Simplification Water all.
14. Pincais	TP	+++++	M		Improvement by Commission Baldio
23. Galegos da Serra	TP	+++	M		Improvement by community

(1) Water allocation principles
1: Time shares
2: Equal shares
3: Plot based
4: Free-to-take
5: First come, first serve
6: Multi-level
5L: 5-Level
TP: Time-Plot
TT: Time- Time

(2) Scheme source flow:
+ 0-0.5 litre/sec
++ 0.5-1 l/s
+++ 1-5 l/s
++++ 5-15 l/s
+++++ 15-25 l/s
(Based on Discharge Measurements in August 1992)

(3) Agro-ecological Zones
HV:High Valleys
M: Mountainous Areas

4. No quantitative basis

Several communal systems do not define rights to water quantitatively. They have only specified the physical boundaries in which irrigation could take place and/or who may use the water, but not how much or for how long. Under these allocation arrangements, two situations are encountered frequently.

In the first situation, there are no rules at all in relation to the division of the water. This situation is typically related to an abundance of water during winter and spring when hay meadows are irrigated. In the summer, this always works to the detriment of the users downstream, who may be cut off when they are irrigating. It is clear that this leads to highly conflict-prone situations (Bleumink *et al*. 1991; Portela *et al*. 1987:22) This '*free-to-take'* principle[53] is mainly found in areas where two or more systems share the same water source and in areas where users from neighbouring villages depend on the same canal. This distribution of water seems to be an expression of a weak social organisation, that may be more common to inter-village cooperation.

In the second situation, that is more frequent, there are two basic rules, although a quantitative assignment of water rights is absent. The first rule is that the physical presence of the interested water user is required. As long as someone is irrigating, and therefore present on his field, he will be respected and other water users will have to wait for their turn ('*first come, first served'*)[54]. People frequently waited for more than a day to get access to water. Even nowadays this is no exception. For instance in the village of Viveiros, August 1993, some people waited nearby the water source more than 10 hours for their turn and even slept there[55]. In this period other farmers did not irrigate at all because they needed to execute other tasks and had no time to wait their turn (Pinto Marques *et al*. 1994). The second rule is that the irrigation of food crops always has priority over meadow irrigation.

These allocation principles are only the basic ones[56]. They will seldom be met in the systems in a pure form. In many systems water allocation is far more complex. First, allocation principles change during the agrarian calendar (see Figure 2.8). Second, in many systems different water rights could exist parallel at different times, for instance the irrigation of meadows during the night or on Sundays and/or Saturdays. These specific meadow water rights indicated and still indicate the influence and power of cattle breeders, mostly the larger farmers, in local society. Also the water sources of irrigation canals can change on a cyclical basis. Portela (1991) mentions that an irrigation canal in the village of Fontim receives the water of a small river but in alternate weeks the canal flow is joined with the water of a permanent spring located in the largest *lameiro* of the village. Another variant of this parallellism is that in some schemes a part of the water is auctioned every year, for instance the Sunday water in the village of Sesmil. The water that is auctioned belongs often to rightholders which are not directly farmers, e.g. the church or the *Junta de Freguesia*. The collected funds can serve for different aims, e.g. maintenance of the church, the functioning of the *Junta de Freguesia*, the construction or maintenance of communal works or to contribute to the annual village feast.

Third, in some systems there is a combination of different water allocation principles at different levels. These topics will be detailed below and illustrated by two case studies in Chapter 3.

There is evidence that in some systems allocation principles have changed over time. Earlier changes tended towards a more detailed definition of rights. This was due to the fragmentation of land holdings and water rights fragmented as a consequence of population growth. In various systems, simple time share allocation seems to have been evolved to complex multi-level allocation (for instance the 5-level allocation in the communal irrigation system of Romainho, see Chapter 3.1). The most frequent result is a two-level allocation system where water is allocated in time shares to groups of users, and within the groups water is allocated to certain plots (plot-based allocation) or, less frequently, according to time shares (for instance the two level time-time allocation in the communal irrigation system of Vila Cova, see Chapter 3.2).

Later changes are more heterogeneous. In some systems the fragmentation of water rights and complexity is still increasing with a clear tendency to involution. At the other hand while inheritance brings about a continuing fragmentation of rights, migration has a countervailing effect: the use of water rights becomes more concentrated (not the water rights itself). Other changes are related to a series of contradictory developments at the local and regional level, leading to agricultural extensification and intensification, both tendencies sometimes taking place in the same locality. Such developments are the decreasing number of water users as result of the massive emigration since the late 1950s, the increasing relative value of labour in relation to water, the decreasing importance of food crops and increasing importance of meadows, different demand patterns for irrigation water linked to the intensification of fodder production and induced by the massive introduction of milk production and the undermining of FMIS. In some systems the number of water users has decreased considerably. This has led to situations in which parts of the original system have been abandoned and fewer plots are cultivated. As a consequence systems with well-defined and determined water rights have changed to a system of more flexible water rights. Most common has been a shift from time shares towards ‘first come, first served’. By this change the water of the emigrants is made available to all resident water users. At the other hand the relaxation of water allocation rules offers more opportunities for farming households with relatively more labour resources to obtain more water than before. But in other systems changes are moving precisely the opposite way.

These changes are related to summer irrigation only. In the winter, permanent meadows, which in most villages lie outside the irrigated summer area, are often irrigated with water from the same water sources, but by a smaller number of users and without the detailed, restrictive rules of summer irrigation. In ‘winter’ the user group with water rights is limited to farmers with hay meadows, while at the same time the water allocation within the user group becomes loosely defined in many systems; the ‘free-for-all’ and/or ‘first come, first served’ allocation rules are normally applied. This is clearly related to the large available quantities of water which allow for the simultaneous irrigation of various meadows. At the time of research only in some mountain systems water rights (time-shares) were defined as specifically in the winter as in the summer (e.g. the villages of Bosto Frio and Torgueda mentioned in Table 2.6). In these systems, too, the length of the summer and the winter periods are rigidly defined (e.g in Bosto Frio the winter period runs from 9 September until 23 June and the summer period from 24 June until 8 September). But it is possible that winter water rights will become more important due to the recent shift in cropping pattern to pastures, principally in the mountains.

In the past the rigid division between winter and summer irrigation was valid for most systems in the research area and clearly related to the importance of the *lameiros* for the wealthier farmers, i.e. cattle breeders. Recently, in many systems the transition between winter and summer irrigation allocation has become gradual, e.g. from 'free-for-all' to 'first come, first served' when the early planted crops (potatoes, vegetables, maize) need some irrigation. When water becomes scarcer at the start of the summer season, the restrictive water allocation schedule is reasserted. In some systems the moment summer irrigation is to start is still each year a conflict-prone issue. Farmers with many *lameiros* want to delay that moment which put them in opposition to farmers which need water for their food crops.

The relation between allocation principles and farm water use

Water allocation defines the share of water to which each water user is entitled. As such, it arranges the division of water at the level of the group of irrigators. The outcome of the allocation of water at system level, in turn, is an *input* at the level of individual farming systems. The entitled share of water is a crucial but not the only factor in the acreage and the types of crops a farmer is able to irrigate. Less obvious, the kind of share a user is entitled partly defines what he can do with his share. In other words, the allocation principle of the system limits the use of water. This is shown in Table 2.7, where I have indicated a number of decisions at farm level that are affected by the kind of water shares (the allocation principles). The table shows whether the choice of irrigated crops is free, whether water shares are bound to a specific plot and whether this water may be exchanged or transacted. In the second part of the table I have indicated the effects that the different allocation principles have on the water application at plot level.

Table 2.7 The relation between water allocation principles and farm water use

Water Allocation Principles	*Water use at the farm level*			*Water application at the plot level*		
	Plot-bound	*Crop choice*	*Exchange of water*	*Flow rate (*)*	*Irrigation time*	*Length of interval*
1. Time shares	no	free	Free	Decrease	fixed	fixed
2. Equal time shares	no	free	Free	Decrease	fixed (a)	fixed (a)
3. Plot-based	yes	restricted	Restricted	Decrease	increase	increase
4. No quantitative basis	no	free/rest.	Restricted	Decrease	variable	variable

Notes:

(*) : in conditions when summer proceeds

(a) : Interval and irrigation time are fixed for each year but differ from year to year because the number of water users in these systems varies from year to year.

Under time-based allocations (types 1 and 2) the right holders are free to choose the plot and the crop they wish to irrigate with their time shares and also to exchange or transact their shares with others. This enables farmers to apply their water on preferential plots, preferred because of the quality of soils, distance to the farmstead, micro-climatic conditions or other reasons. This makes it possible for them to respond flexibly to the water requirements of specific crops; some crops can be irrigated more frequently than others. It has been found, for instance, that in time-share systems farmers prefer to direct part of their shares to a specific plot where vegetable crops (with a shallow rootsystem) are grown, which are more vulnerable to wilting.

Under equal time shares (type 2), the use of the water on preferential plots goes without saying, since normally every user has one, non-dispersed time, relatively large time share that has to be divided among the irrigated plots. This type of allocation has the advantage that the labour input in irrigation activities is compacted: each farmer has to irrigate only once during the system's interval. However, the efficiency of water use at system and farm level may be rather low, since carrying water to several plots within one's turn requires much travel time of water and consequently causes conveyance losses in the earthen channels.

In variable time share systems (type 1), the freedom to apply water to preferential plots implies that (part of the) water assigned to one plot is directed to another. This freedom is often used to apply the water to more drought-sensitive crops (vegetables with a shallow root system). However, this freedom is limited in practice, since the water must be passed on to the adjacent plot of the next water user after one’s share has ended, and the use of the water on other plots depends on the physical possibilities of passing it on. Irrigating distant plots may be less profitable because conveyance losses are great, and because the travel time to distant plots might even exceed the time of the share when the shares are small. Extra water losses will have to be paid by the farmer who wants to use the water on another plot. Consequently some users apply most of their shares to the appointed plots and only combine shares when the plots are near. In variable time-share systems (type 1), the total irrigation time of farmers is often fragmented; at different moments during the irrigation interval they have to show up to irrigate different plots. This also fragments labour input in irrigation and affects the overall organisation of farm work[57]. The overall water use efficiency within these systems (type 1), as compared to fixed time systems (type 2), is higher since fewer water ‘jumps’ are made and consequently canal water losses are reduced.

Table 2.7 shows that under the time-based allocation principles, each farmer knows exactly when and for how long he receives water but he does not know exactly what flow will be available.

Plot-based allocation is plot-linked by definition. The water that is assigned to a plot may not be used on other plots and may not be exchanged either. This rigidity is comprehensible because the measurement of allocation is based on the time needed to irrigate the plot. This time depends on the size of the plot, the kind of crop and the water application method. In this type of allocation a farmer does not know exactly when the turn for his plot is due because that depend on the water supply and the irrigation of the other plots in the rotation. When summer proceeds, water supply is decreasing and consequently irrigation intervals are increasing. To avoid long-lasting irrigation turns in these systems, farmers are not allowed to grow crops which consume a lot of water on the irrigated plots. In practice this ban concerns meadows; the contour ditch method used for meadows consumes much water (and consequently irrigation time) compared to the irrigation methods of food crops (short furrow and small basin type). This is not justified at the time when water is scarce and should be available for food crops. Thus production for household consumption has priority in summer irrigation. In many households even all available water is used for food crops. This is so ingrained in people's minds that it appears to be a social norm. Even in schemes with other allocation types (in which no restrictions on meadow irrigation exist), it will be experienced as anti-social behaviour to irrigate one's meadows when in a neighbour's plot potatoes or maize are wilting. This behaviour is censured by the community. This is probably due to the fact that up to the 1950s periodic hunger and abject poverty were widespread. Considering the specific historical social relations in the Trás-os-Montes villages characterised by a sharp social stratification but with strong family ties as well as a great interdependence between social groups and a certain sense of 'communalism', there is a certain social logic in prioritising water use for food production. However, irrigation practice is changing. Food production in quantitative terms (but not in the qualitative, cultural dimension) is losing importance since households have become smaller. Irrigation of meadows instead of food crops during the night is common already.

In systems without a quantitative basis for water allocation (type 4), farm water use is not only restricted by physical limitations such as water availability. Also under the 'first come, first served' allocation principle, the irrigation of meadows is prohibited in the summer, for the same reason as was explained when plot-based allocation was discussed. Moreover, households with more resources than others (such as labour to wait their turn) have more opportunities to mobilise irrigation water.

The sale of separate water rights is allowed only under time-share allocation (type 1), however in many cases this will not be easy in practical terms especially if time shares are short and are part of a tight rotation schedule of many plots. Under time-share allocation exchanges of irrigation turns are also allowed with the same practical restrictions already mentioned. In equal time-share systems (type 2) all water rights are temporary and cannot be individual property because they are tied to the actual residence of the water users and effectuated by their contribution to the yearly reproduction of the system. This implies that water users may only sell or exchange their irrigation turns in one specific year. Under the plot-based irrigation schedule the sale of separate water rights and the exchange of irrigation turns is not allowed. The plot and its water right are inseparable, they can only be sold as a whole.

In all systems, flow rates decrease during the summer, but the consequences differ. Under plot-based allocation (type 3), a decrease in water flow implies that the length of the irrigation turn per plot increases and consequently the length of the irrigation interval also increases. Under two-level allocation (time-plot), where at the first level water is assigned to a group of users on a time basis, this may imply that some water users cannot irrigate during the turn of their group. Normally, this is compensated for during the next turn. Under time-share allocation, the length of the irrigation interval is fixed. The flow rate diminishes and with it the possibility to irrigate the entire plot, which tends to lead to under-irrigation.

To summarise: the principles of water allocation and related rules for distribution determine the degree of flexibility of water use at farm and plot level[58]. The bases for water allocation have implications for land use (crops, plots, intensity) and the allocation of labour and inputs.

In Chapter 6, I will show the implications of the water allocation principles on the use of the extra water in the system that could be made available by external intervention in the systems. I will also indicate how this has influenced the realisation of the production objectives of this external intervention. First we shall see the complex translation of water allocation in water distribution practices.

Water distribution

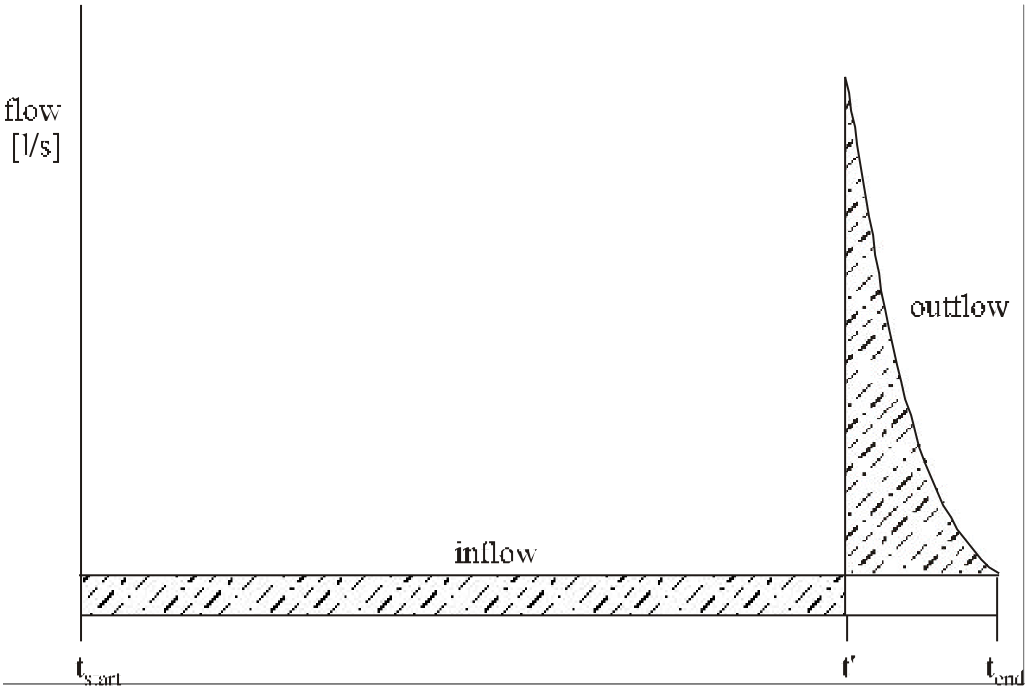
In general it could be stated that distribution practices have been developed to meet the requirements of the underlying water allocation (distribution of rights) but water distribution, defined as the physical distribution of water among the users (Martin *et al.* 1987) has some specific characteristics in the conditions of Trás-os-Montes. On the one hand the fact that in the majority of the systems only one farmer is irrigating at a time with the available flow simplifies distribution. On the other hand distribution also has complex features. In the first place, discharges from the water sources in the summer are often too low to irrigate directly. Moreover transport losses in the canals may be high and consequently the time that water needs to travel between source and plot. Another factor is the fragmentation and scatteredness of plots and water rights through sale and inheritance that results in an increased relative water scarcity. Formerly one landowner had more room for manoeuvre to make a plan for the summer period: which plots to sow with what crop taking into account his prospects in relation to water availability (Bleumink *et al.* 1992).

In many cases, the result of these factors is that water for an individual water user would become almost unmanageable, e.g. it is impossible to irrigate a plot, which is located 800 m from a water source with a discharge of 1 l/s, by means of an unimproved earthen canal for only half an hour. Water would never reach the plot (Bleumink *et al.* 1992). In other words, mechanisms are needed which convert rights into real, usable flows.

Two elements are of crucial importance in the conversion of water rights into flows (see Figure 2.8):

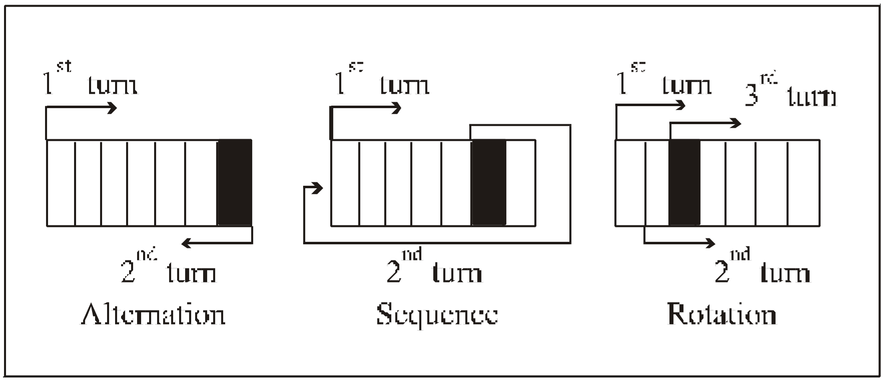
Distribution and storage infrastructure. The most important facilities are reservoirs (*poças*). They are most frequently associated with water sources with low discharges. Most reservoirs aim at obtaining manageable flow rates for field use[59]. Each water user or group of water users (distribution group) stores the water corresponding to his/its time share in the reservoir[60]. Its operation is as follows (see Figure 2.9): when his time share starts, the water user (or group) closes the reservoir (t_{start}). Some time before the end of his time share he opens the reservoir at t'. A larger outflow than the permanent inflow will be obtained which will be more suitable for field irrigation. Also transport losses will be minimised. At the end of the time share of the water user (t_{end}), the next water user (or group) closes the reservoir again to store his time share etc. In combination with the flow regulation function, reservoirs may have other specific functions and attributes. Examples are: reservoirs at the plot and farm level, night reservoirs, reservoirs equipped with an automatic siphon (*pedra de engenho,* see Box 2.10), double reservoirs[61] etc. Many reservoirs (except the ones with an automatic siphon which are used in the winter) are only used in the summer. Outside this period, water flows are normally sufficient to irrigate directly. In Chapter 7 I will discuss in some more detail the labour-saving potential of reservoirs, crucial for the improvement of the systems.

Figure 2.9 Inflow-Outflow Hydrograph of a Reservoir



Distribution rules. Water users have developed also a set of complex mechanisms, rules and practices to distribute the water according to the allocation. Distribution groups are formed in some systems, mostly with highly fragmented irrigated plots and water rights. In the two-level time-plot based allocation water is allocated to distribution groups (named after the original households or *casais*) on a time basis (normally one day or a part of a day) and within this group water is distributed to a number of specific plots. Often not all these plots will receive water in the course of one irrigation turn. But compensatory/balancing mechanisms are present to secure a fair distribution of the scarce water between the members of the group over the whole summer period (see Figure 2.10).

Figure 2.10 Balancing/ Compensatory mechanisms in distribution groups



Source: Bleumink *et al.* (1992)

Notes:

alternation: a group of plots is irrigated from upstream to downstream during one turn, from downstream to upstream during the next turn

sequence: the first plot that was not (sufficiently) irrigated during the last turn will receive the water as the first in the next turn

rotation: the first plot to be irrigated will rotate in subsequent turns

These *compensatory mechanisms and rules* are not limited to distribution groups. They are present in the whole functioning of the irrigation systems, i.e. who starts irrigation will depend from year to year and/or from turn to turn; in many systems the sequence of turns will be reversed from year to year or/and alternated from turn to turn[62]. Although streamflow normally decreases during the summer, these mechanisms compensate for the variability of streamflow (principally caused by normal and irregular rainfall) from year to year, from month to month and from turn to turn in a random way. In the case of a group reservoir these rules cancel out over longer time spans the variation of the reservoir outflow to a certain extent over the users[63]. The same type of rules apply to the alternation of night irrigation[64] and any reductions of irrigation times in order to compensate for the travel time of water in the channels between the source and the various plots.

In synthesis, these rules are fundamental in the conversion of water allocation in the physical distribution of water. Through these rules each water user is confronted with the same conditions of operation – averaged over time – regarding flow variations, the timing of irrigation turns etc. These rules result in *the smoothing out of variations in flow* available for irrigation and the creation of average *equal conditions* for all users to obtain the water to which they are entitled[65]. They are very important characteristics of FMIS in Trás-os-Montes. These rules or mechanisms are basic for a correct translation of allocation into distribution. Compensatory/balancing mechanisms combined with the outflow characteristics of reservoirs under different modes of operation present an important design potential which can be purposely used in the (alternative) improvement of systems as will be discussed in Chapter 7.

The management of the systems also implies other rules, for instance the mixing and separation of water of different sources; the right of way; the passing of water and the use of private channels. Often there is a certain synchronisation and coordination of farm activities because of the shared use of irrigation channels, the access of draught cattle, tractors and equipment to the plots. In the village 'Galegos de Serra' the farmers use expressions like *caminhos sabidos* ('known paths') to indicate that in summer farmers have the right of trespassing other farmers' plots for 8 days to reach their own plots in order to prepare and plant them. Also water is prohibited to flow in the channels during certain periods in order to drain the plots and to plough and to manure them (*águas sabidas* or 'known waters'). A similar coordination of farm operations is documented by Portela (1988:200) in the *veiga* area of the village 'Fontim' in the 'Terra Fria'. These rules and practices are products of history and tailored to the specific local situation and conditions of each irrigation system. That makes the management of these systems a truly local art.

In conclusion, water distribution is essentially shaped by both *water allocation* and *water availability*. In spite of their interdependence, I identify these three parameters as discernible *key elements* which determine the diversity found among the irrigation systems. These parameters can be changed by intervention and as such constitute building blocks for intervention purposes. I will return to this issue in Chapter 7.

2.5 Dynamics and stagnation in farmer-managed irrigation

FMIS in Trás-os-Montes are relatively successful in achieving the objectives for which they were created. Evidence is their long existence, their reproduction over time and the continuing use made of them. On the other hand more and more FMIS are in a process of decay and stagnation, both for internal causes and external factors.

To be sustainable, FMIS need to be *dynamic* systems, having to respond to the (changing) needs of the users. Insofar as the actual functioning of FMIS does not correspond to changing objectives, resources and interests of farmers, the latter will try to adapt, change or improve their schemes. Attempts to overcome environmental constraints and rigidities in the functioning of the schemes will be made. If the schemes do not or cannot respond satisfactorily to the needs of (groups of) water users, farmers individually or in small groups also look for opportunities outside the communal schemes in order to develop their own water resources and strategies to adjust irrigation to their changing needs and resources. In turn, these strategies and the development of new water sources could contribute to the undermining, stagnation and abandoning of the FMIS.

Empirical evidence shows that water users themselves actively intervene in irrigation development, both inside and outside the communal systems. Here I will distinguish the following *types of strategies and interventions*:

Adaptation strategies

Within the restrictions and limits of a particular system, water users try to make the most out of the generally small quantities of available water. Many strategies can be distinguished and grouped in two categories: making water distribution more flexible and obtaining more water. Water distribution is made more flexible through exchange of water turns or, more general, the reciprocal *exchange of different resources*. A survey in 1986 among the 125 farmer households of the village Cimo de Vila de Castanheira revealed the existence of 20 relations between farming households in which water was exchanged for other resources, principally labour[66]. Water users explore opportunities to make individual or group arrangements among themselves within the limits set by the management and physical constraints of the systems. Land and/or water of *emigrants* is used by other water users through various arrangements. A case study of the village of Sezelhe (Morgado 1993) in the mountain zone of Barroso showed that of a total irrigated area (winter and summer areas) of 125 ha, water users irrigate 17 ha of land (or 14 per cent of the total irrigated area) that is property of emigrants. In this way the plots are cultivated and do not lose their access to irrigation water[67]. Plots with access to irrigation water, both in the winter and/or in the summer, are much valued, therefore they are also frequently leased.

A range of local *agronomic practices* are used for adaptation to or escaping from various degrees of water scarcity involving a detailed local knowledge of soils and crops. Examples of *l'art de la localité* are the combination of soils, crops, crop uses, rotations, varieties, plant, sowing and harvest times, plant densities etc. Agronomic practices[68] to make the most adequate use of scarce water resources, include:

- Use of balanced cropping patterns: a specific proportion between irrigated, partly irrigated (e.g. hay *lameiros*) and unirrigated (e.g. rye but also part of the maize, potatoes and annual fodders) crops which is globally adapted to the existing water availability at the farms. Even normally irrigated crops are sometimes consciously not irrigated e.g. when seed potatoes are multiplied for farmers' own use: imported seed potatoes are mostly sown on dry and less fertile fields in order to yield a lot of small potatoes which constitutes highly appropriate seed material for the following year. In irrigated conditions yield would be higher but also the size distribution for seed material would be less appropriate.
- Planting or sowing of different crops in distinct periods, e.g. potatoes (March-April) before maize (May-June).
- Earlier seeding and planting of crops to avoid water scarcity. There are differences in planting dates between different zones and also between the farmers of the same area reflecting differentially increasing risks of frosts and heavy rains at earlier seeding times and differential risk behaviour of farmers. Although risks (e.g. night frost) are higher, some potato fields are planted early (March or even in February[69]). In this way these fields can receive some irrigation water in May and June before water scarcity conditions normally set in and the rigid summer allocation will be implemented.
- Use of different plant varieties depending on water requirements, drought resistance, planting dates and crop uses. For example hybrid maize has higher water requirements, is less drought resistant and has a longer growth period than the regional, rustic varieties. The longer growth period of hybrid maize is also related to its use as silage whilst the regional varieties are used as green fodder or harvested as corn.
- Promoting good rooting of crops (e.g. maize), growing on the stored soil water, by not irrigating in the first growth period. This also has the advantage that in subsequent

irrigation turns deep percolation losses outside the root zone of the crop are minimised and eventual rain can be used more effectively.

- Timing of irrigation in the critical growth period of the crops, e.g. in the flowering/tasseling stage of maize and during tuber initiation/growth of potato.
- Relay planting or sowing of other crops (e.g. beans in potato fields, annual grasses in maize fields) which can use the soil humidity in the rootzone that is left after the main crop is harvested.
- Frequent weeding and hoeing in order to prevent losses of nutrients and water taken up by weeds and to disturb the capillarity of the upper soil layer in order to prevent water losses.
- High sowing density of maize. Dependent on irrigation water availability and rainfall, farmers assess the possibilities of crop yield and survival. Normally they thin out the crop two or three times. The plants with most hydric stress which are not able to yield grain serve as green cattle feed. In that way, crop density could be a half or a third of the initial density (Rebelo 1987). In case of large water shortages only a part of the plot is irrigated.
- Irrigation of alternate furrows (Pinto Marques 1994) to apply small overall water depths per irrigation turn. This practice has also the potential to increase the effectivity of eventual rainfall.

Irrigation facilities, both of a traditional type (shallow wells, earthen reservoirs, *pedras de engenho*) and of a more recent type (tubewells, concrete tanks, sprinkler irrigation) at plot/farm level have a strategic importance for decreasing water use and labour input and making them more flexible. These irrigation facilities are e.g. used to:

- permit a more flexible and improved timing of water application not prescribed by the rigidities (e.g. a long irrigation interval) of the system. By means of temporary water storage in reservoirs (*poças, tanques*) it is possible to irrigate in the period between two turns. In this way the irrigation interval can be adjusted to the irrigation timing requirements of crops, principally vegetables.
- irrigate plots which otherwise cannot be irrigated. By means of pumps and flexible tubes water can be transported to plots which are higher up and more remote.
- irrigate plots with a convenient discharge that is neither too low nor too high dependent on crop and irrigation method. To some extent pumps and reservoirs permit to regulate the discharge.
- irrigate meadow plots more efficiently and uniformly in the summer period by means of sprinkler irrigation[70]. EU funds are available for some groups of farmers.
- irrigate with less labour input (*pedra de engenho*, sprinkler). Sprinkler irrigation in Trás-os-Montes is a relatively recent development, principally in FMIS. Farmers who use this irrigation method normally own a few sprinklers and a plot reservoir. Mostly the sprinklers are operated by the water pressure from gravity (using differences in altitude) and sometimes by pumps. The labour-reducing potential consists in that after setting the sprinklers presence of labour is no longer required until the next

setting of the sprinklers contrary to the surface irrigation methods in which the irrigator needs to be on the field.

- permit greater flexibility in labour input using tanks or plot/farm reservoirs, particularly important in the combination of farm and off-farm activities. Therefore these *tanques* are frequently found in systems near cities with off-farm employment opportunities (Portela 1990: Anexo II). Moreover, an irrigator is no longer tied to a fixed interval.

** Changes in Water allocation (principles) and water distribution practices.*

In some systems farmer communities have changed water allocation patterns and in other schemes discussions are taking place (see Table 2.6). These changes are the outcomes of complex social processes, because this type of changes could imply changes in social relations and resources which farming households control. Some (groups of) water users will expect to improve their situation while others will oppose changes[71] because they perceive the actual water allocation and distribution as satisfactory while changes may imply risks (see Chapter 3.1). In conditions of water scarcity, actual water distribution is the reflection of a delicate balance between everybody's vested interests.

Because of the changing context, the ability to change the rules and to craft new rules will be crucial for the future of these systems as argued in Chapter 1. This is exactly the problem in many of these systems because there are no clear mechanisms and arrangements between the users for changing the rules.

Usually long time periods are needed but changes nevertheless occur, especially at specific events that offer *opportunities for change*. Transactions and continuing division by inheritance of land and/or water are used as such. External interventions in irrigation systems have the same potential, e.g. in the village of Sesmil, the improvement of the communal system (MRT intervention) was used as an opportunity by a group of water users headed by a local leader to change the distribution of water rights, linking the new distribution of water rights to the labour contribution of water users in the improvement works (Pinto Marques 1994). The village of Roriz is another interesting exemple. The old system in which water distribution was based on (very) unequal time shares, had been abandoned for years. When rehabilitation took place, all households in the village (approximately 100) had and took the opportunity to obtain equal shares of the available water in the summer period by means of equal labour or money contributions in the rehabilitation works[72]. This has led to a hybrid type of allocation. At first sight the new allocation principle is Type 2 (equal time shares) but it is not. Fundamental features of Type 2 allocation are that water rights are temporary and village bound. But the new shares have been attributed to specific individuals by investing their labour force or money in the rehabilitation works. They can freely dispose and transact these water rights which are typically Type 1 (time shares) features. On the other hand the water share of a user is not fragmented: he has to divide the irrigation water of his time share over his plots. This is a typical Type 2 feature. The water allocation is still more complex because the owner of the plot in which the water source of the system -a spring- is located, has the right to use the water in summer on Sundays while in the winter period (s)he has the exclusive right to use the water.

Also a change of external conditions may constitute an opportunity. In the village Vilar de Lombo a Type 1 water allocation existed with very unequal access to water among water users but with equal obligations in the maintenance of the system. This was experienced by a lot of farmers as injustice. The group of water users which had little access to water used the 'Carnation' Revolution of 1974 to impose a change. Water rights were equally distributed among all households in the village, in spite of fierce water right holders protests and attempts to re-establish the status quo by means of juridical procedures.

** Improvement of Irrigation Facilities.*

The largest physical constraint in many irrigation schemes in Trás-os-Montes is the *scarcity of water* in the summer period at scheme and field level. Numerous (partial) improvements of irrigation facilities implemented by the farming communities themselves have been found and still are made. Findings from the first inventory study show that in 11 out of 23 villages, parts of the infrastructure have been improved by the water users themselves (Bleumink *et al.* 1992: 28). These improvements usually consist of the lining of (the critical parts of) canals and reservoirs. This type of improvements is frequently the result of joining resources of the water users (labour) and a local (State) organisation like the *Junta de Freguesia*, *Comissão de Baldios or Câmara Municipal*. Mostly improvements are implemented in stepwise fashion, that is to say, in one year e.g. lining a reservoir, in another year lining some parts of the canal etc.

** Individual Water Resources Development.*

Since long, farmers have also developed water resources, traditionally springs, wells and galleries[73] on their own plots[74]. The rationale is obvious: individual water sources imply more control and access to water, surpassing restrictions of water use found in the communal systems. Also the exploration of individual sources could save labour compared to the operation of the collective systems. Concerning the quantity and density of individual water sources, a remarkable difference exists between the Mountain areas and the High Valleys. *Hydrologic conditions* in the High Valleys in which small scattered sources originating from subterranean water dominate in irrigation (see Table 2.1) were more conducive to development of water sources on an individual base: discharges from many of these sources are too low (in the range of 0.05 to 0.3 l/s) in order to permit communal use. But recently, two factors have enormously accelerated the search for water and the development of private water sources in some regions. They are the impact of *emigration* and the spread of new *water technologies*.

One of the effects that returned emigrants have had on local society, principally in the 1970s and the early 1980s, was that they brought back with them capital to be used for investments in water sources development on an individual base. At the same time, new technologies became available that was supportive to this type of development (Davidse 1991).

Long PVC tube lines made it feasible to transport small quantities of water from long distance water sources to the best plots nearby the villages and therefore to reinforce available water from the traditional systems and/or to decrease dependence on the traditional communal systems. This technology made it possible to explore springs and other water sources which were hardly used before because they were located far away from suitable plots. This stimulated the creation of small enterprises to develop water sources and to dig trenches for the tubes. The increasing availability of electrical supply at village level has made possible the drilling of tubewells[75] equipped with electrical motors and submersible pumps. The development of sources for drinking water and the construction of home connections by State institutions is also quite recent. Another recent technology widely used in Trás-os-Montes, principally in the High Valleys, is the use of small motorpumps and tubes for the transport of water. Many are used to extract water from private shallow wells, but this technology also calls into question the boundaries of collective systems. The use of these motor pumps permits the extraction of water directly from the water sources and the irrigation of fields which formerly could not have been irrigated by gravity. Moreover, the pumps make the farmers independent of the functioning and operation requirements of the collective systems. The motor pumps could be used at whatever time outside the allocation calendars of the traditional systems. These new technologies led to an increasing disconnection between where and when the water is extracted and is applied.

Stagnation and undermining of FMIS

I will illustrate the stagnation and decline of farmer-managed irrigation by two examples. The first (Gusmão 1993) shows the impact of the massive emigration on irrigation practices and the reproduction of FMIS. In Calvão functioned 5 collective irrigation systems. The emigration of many inhabitants led to the abandonment of these systems. In 1993 only two were still partly functioning. One of them was before used by 50 households, five water pools (*poças*) in the riverbed supplied a canal of 1900 m length before entering the irrigated area near the village. The abandoning of the system was gradual in time: first the *poças* were not reconstructed anymore, water flow diminished, which led to a diminishing use and increasing abandoning of the canal. In the end only some farmers continued to clean a very small part of the canal near the river to irrigate some plots.

Along the canal most plots are now shrub-covered and some planted with vines. In the village area only some of the plots are still irrigated but by individual sources (shallow and deep wells) and here also many plots are covered with shrub. At the same time the largest part of the river flow is now used by owners of motor pumps who transport the water with tubes to the plots they prefer.

The second example (Ferreira 1992) shows the vicious circle of the rush to create individual water sources. In the hamlet of Ervedal, the only public water source for domestic use gave its last drop of water in May 1992 when a local farmer decided to drill a deepwell of 80 meters in order to '*recuperate the water that other tubewells robbed from the well that I had here and which always had water*'. Then he was pressed by the local population, Junta de Freguesia and the municipality to dismantle the pump. '*I never thought that the deepwell would affect the source*' apologised the farmer who then also stayed without a drop of water to drink. Some inhabitants of Ervedal wanted to put the case before a tribunal but the Junta de Freguesia asked to withdraw the complaint. Waiting for a definitive solution, the problem was provisionally resolved by the municipal fire brigade which trucked water to the inhabitants of Ervedal two times per week.

These examples show that the recent tendency of stagnation and decline of FMIS has several dimensions and causes which re-enforce each other in vicious circles.

First, access to water is increasingly individualised. The rush to create and use individual water sources has led, in various villages, to the undermining of existing irrigation schemes. Their sources have been directly or indirectly captured by individual water users. Motor pumps and tubes are directly used to extract water from the source without the need to use the canals of the FMIS. For these reasons the available water has decreased to such a degree that some communal systems have virtually died. Striking examples can be found in villages in the High Valleys where since the 1970/80s under influence of the building of collective milking parlours (SCOM[76]) and investment subsidies for 'viable' farm development, farming became principally oriented to milk production. That required more water for better and more cattle fodder, being the summer months critical because of the physical scarcity of water. Many farmers have made enormous investments to explore small quantities of water. Moreover, investment subsidies for individual water resources development exist for farmers who comply with certain eligibility criteria.

The undermining of communal systems is further aggravated by the effect of migrants spending their August holidays in their villages. At such times the population of an ordinary village will double or sometimes triple. The combination of this sudden population influx with their more demanding water consumption habits (car washing etc.), leads to high requirements exactly in one of the driest months.

Second, the relative value of water in relation to labour has undergone a profound change in comparison with earlier times. This is clearly illustrated by the following example (Pinto Marques *et al*. 1995: 25): In the village of Nozelos the farmers are abandoning their FMIS because of the low streamflow in the canal. They say that it is not rewarding to clean the canal because 'for the water that can be seen in the canal it's not worth the work' ('*para a água que se vê não vale a pena o trabalho*'). At the same time the water of the brook, the water source for the FMIS, is used by farmers that have motorpumps and transport the water by tubes to their plots.

Third, there is a clear tendency to involution, the only changes in many systems are a consequence of the application of existing rules which is reflected in a further division of plots and water rights but modified rules better adjusted to the new context are not emerging.

Conclusions

In this chapter I have elaborated on the functioning of farmer-managed irrigation systems in Trás-os-Montes and the context in which they are embedded.

Irrigation cannot be understood as an isolated phenomenon but is interwoven with the farming system and the local community. Food production depends on summer irrigation. Fodder production is principally dependent on ‘winter’ irrigation of *lameiros*. Within the natural restrictions and variability in space and time (climate, water availability), specific irrigation practices developed parallel to the improvement of other natural conditions (terracing, manuring).

A great variety of irrigation systems has been created as the result of the joint efforts of their users. Their physical infrastructure is rudimentary and the system’s operation is simple but complex rights of access to water and corresponding distribution practices have developed in time.

The interplay of natural and social factors resulted in highly efficient but labour intensive irrigation practices. The outcome of a changed context in which farming and irrigation are embedded, characterised by labour shortage, is a very heterogeneous picture of the dynamics and stagnation in these irrigation systems: the majority of the systems continue functioning and in some systems improvements are still made by the users. At the same time in many systems a clear tendency towards involution is taking place, principally in the Mountains. At the other hand there is an unmistakable tendency towards the creation of individual irrigation facilities (principally in the High Valleys) which leads towards the undermining of existing communal irrigation systems.

This complex picture is also reflected in the irrigation intervention programmes created by the State: both improvement of communal irrigation systems and the development of individual water resources is stimulated and subsidised as will be discussed further on in this thesis.

In the next chapter two case studies are presented of the functioning of farmer-managed irrigation systems in Trás-os-Montes in order to give a concrete illustration of the most important issues dealt with in this chapter.

Notes

1 The term ‘Farmer-Managed Irrigation System (FMIS)’ will be used for all those schemes which are constructed, maintained and managed by farmers, both collectively or individually. The Portuguese call them ‘*regadios tradicionais*’ (traditional irrigation systems). The qualification ‘traditional’ indicates that these schemes generally have a long history. Until the 1980s State intervention in ‘traditional’ FMIS was nil or minimal.

2 The importance of the small-scale farming sector in Portugal is illustrated by the following facts. According to the agricultural census of 1979, smallholdings of less than 10 hectares account for 94 per cent of all of Portugal’s farms. These smallholdings occupy 24 per cent of Portugal’s cultivated and forest land but contribute more than half of Portugal’s gross domestic agricultural product (Cordovil *et al.* 1986).

3 At the same time provoking its misuse. Pires (1999a) gives the example of irrigated sunflower, a subsidised crop mostly cultivated at large farms. The farmer applies one or two irrigations or even not any in order to receive the corresponding subsidy but the ‘irrigated’ sunflower in many cases is even not harvested because it is not in conditions to be sold, a strategy popularly called ‘giracídio’ or literally ‘sunflower killing’.

4 In Trás-os-Montes farmers say ‘water is the blood of the land’.

5 The definition of (traditional) irrigation system applied here is not very precise. Basically two elements come to the front: the idea of a collective character of the irrigation system (*a levada* or *o rego do povo*: the people’s irrigation channel) and the type of water sources are limited to surface water and springs. According to Gusmao *et al.* (1987) ‘ The term traditional perimeter covers all areas irrigated by micro-irrigation systems already in existence, of a collective nature and set-up on the initiative of the farmers themselves’.

6 The census does not order and aggregate data according to agro-ecological zones but according to administrative divisions. Therefore, in this statistical exercise the Mountainous Areas are assumed to coincide roughly with the municipalities (*concelhos*) of Montalegre, Boticas and Vila Pouca de Aguiar; the High Valleys with the municipalities of Chaves, Valpacos and Vinhais. However, it must be noted that one part of the municipality of Vila Pouca is clearly High Valley zone and a part of the municipality of Vinhais has more mountain characteristics. Here certain parts of the Vila Real municipality with clear mountain characteristics (Alvão mountains) are also not included.

7 Here also diverse sources are giving considerably different statistical data. IFADAP (1994) mentioned for 1993 an irrigated and an irrigable area in the region of Alto Trás-os-Montes e Douro of respectively nearly 75,000 ha (about 15 per cent of the actually used farm land) and 115,000 ha. These are probably grossly overestimated values.

8 SAU: *Superfície Agrícola Utilizada* (in English: actually used farm land). In the SAU are included cultivated arable land, temporary fallow land (a widespread practice in the cereal production lands), family garden, permanent crops and permanent pasture lands. Not included are pure forest stands and the lands that was before cultivated but abondaned for economic, social or other reasons and that do not enter in a crop rotation cycle as temporary fallow (DRATM 1991). The SAU is different from the total farm land (*Superfície total da exploração*).

9 People use expressions like : ‘*Em Agosto a água vale ouro*’ (in August water has the value of gold) and ‘*Em Setembro secam as fontes e ardem os montes*’ (In September the sources dry up and the mountains are burning)

10 Local people frequently refer to these uncultivated plots as being ‘in mourning’ (*estes terrenos estão de luto*).

11 Peixoto dos Santos (1995) mentions the existence of the following exchange relations for the village of Pereira (33 farm households): 11 households exchange labour for machinery services; 8 households exchange labour for animal traction; 10 relations in which labour is exchanged for water turns; and 3 households exchange irrigation water, for instance summer water for winter water. The last exchange relation reflects the crucial importance of winter water in the irrigation of hay meadows for cattle breeders.

12 The small-scale farming sector in Portugal has an importance that goes far beyond the level of agricultural production realised. Among other contributions to the Portuguese economy, it is the main supplier of cheap industrial labour. Whole industrial sectors like the textiles industry in the North have been based on the labour of small farming households. A case study of two parishes in the neighbouring Minho region (Fragata 1989: 169) reveals that about 60 per cent of farming households have a member working in nearby industry. It was calculated that the contribution of farm production for household consumption and the locational value of the farmhouse represents 67 per cent of the industrial wage that these workers earn. Thus, should these households dispose of these use values, industrial wages would need to increase by 67 per cent in order to maintain the same level of income.

The importance of use values is frequently overlooked in agricultural modernisation programmes aimed at the creation of ‘viable’ farms. An assumption of these programmes is always that to realise this objective a large percentage of the farms need to disappear. In that respect Fragata (1989: 179, 180) analyses for the two parishes the potential effects on the state treasury of a programme to stimulate old farmers to withdraw from their small farms. In this category of farmers the monetary saldo (farm production for the market), autoconsumption and the state pension represents respectively 12, 58 and 18 per cent of the total income of the household. Maintaining the same income, the question could be posed what the value of the new state pension should be if an old farmer passes into the category of pensioners with a small garden in which autoconsumption represents 34 per cent of the total income. In that case Fragata calculated that the state pension needs to represent 61 per cent of total income, increasing its value in 1984 from 4,000 escudos to more than 13,000 escudos. For the 13 households of farmers-pensioners in the two parishes studied, this will represent a social security cost of 2,226 contos (1 conto = 1,000 escudos) per year. If these farmers withdrawn there will become available for the use of other farmers 5.8 ha which implies that one hectare will cost to the state treasury 386 contos (about 2300 US$ at 1989 price level) per year, an exceptionally high cost.

13 In this respect the enormous development in the 1980s of small-scale dairy farming is remarkable. This development was made possible by the construction of collective milking parlors (SCOM*: Sala Colectiva de Ordenha Mecánica*). Dairy farming is a profitable activity, which is often combined with off-farm work. Two dairy cows represent an additional stable and a steady source of income comparable with the wage of a construction worker (Besteman 1989). In the region of Entre-Douro-e-Minho limited off-farm opportunities for women have encouraged them not only to remain in agriculture but even to increase their agricultural work through small-scale dairying.

14 It is interesting to note that whilst economists, agronomists and policy-makers expected the small holder sector to disappear in time (as happened in some other European countries), pluri-activity paradoxally reinforces this sector because it will be much less affected by external and market forces. The wages are not enough for a decent livelihood, so farming is a necessary complement and vice-versa. The really poor people in the Portuguese society are to be found in the big cities where they are exclusively dependent on wage labour. I remember that in 1992 the newspapers quoted a report of the Catholic church about the existence of abject poverty, including hunger, comprising a considerable part of the population in the city of Setubal, one of the most important industrial centres of Portugal.

15 In contrast to the interior regions, nearby the cities of Lisboa and Porto numerous small farms produce vegetables for the market.

16 Winter irrigation of meadows was general practice in many mountainous areas in Europe, principally in the central parts (Dias *et al.* 1986: introdução).

17 A. Coutinho noted already in 1884 that the value of a meadow plot would triple if irrigation water was available (quoted in Portela 1988:201). Gonçalves (1985:24) gives a range of yields between 2 ton of dry hay in rainfed conditions to 6 ton in irrigated conditions.

18 Farmers in the mountainous areas say: *Água limpa é só para limpar a cara* (clean water only serves for washing your face).

19 In the neighbouring Spanish region of Galicia it is called *aguas gordas* or 'fat' waters.

20 In another context, a similar use of mineralised groundwater seepage and surface water rich in manure and humus particles from higher-situated arable land was made in the 'Achterhoek' region of the Netherlands. The following summarises some relevant points from an article written by Baaijens (1991). A system of constructed supply canals (*beken*) led these 'fat' waters to low-lying meadows (*vloeiweiden*). Around 1850, for different reasons and interests (forestry) these *vloeiweiden* started to decline. It was propagated to abolish the original irrigation function of *beken* and to use them instead for drainage by deepening the *beken*. That led to the desiccation of the higher, heavily manured, arable lands whilst the lower parts still remained too wet and moreover only received rain water leading to the leaching of nutrients. An improvement of the drainage on these lowest parts implied that leaching was provoked. After the 'improvement' the meadows became poorer in nutrients and flora composition (grasses were replaced by mosses), land rent and sale prices halved. The *vloeiweiden* have been

pictured systematically as models of backwardness, amongst others by Winand Staring, one of the founding fathers of agricultural modernisation in the Netherlands. Generations of rural water engineers (‘*cultuurtechnici*’) started persistently ‘improvements’ on the wrong places. There is no *beek* which in the 20th age was not ‘improved’ various times whilst there is still flooding in the lower parts and at the same time water supply is requested for the higher parts. And this while every farmer could tell what the function was of these *beken* and how the system worked. All in all, hundreds of millions must have been spent on these canalisations. The result is the desiccation of the landscape to such a degree that even a part of the domestic water for the ‘Achterhoek’ need to be transported from a neighbouring region, the ‘Veluwe’. Only recently, in the framework of a new approch to agrarian development in combination with water management and conservation, a renewed interest in these *vloeiweiden* is emerging.

21 They are also expressively called *hortas de gado* or ‘cattle gardens’ (Trigo de Abreu *et al.*, cited in Gonçalves 1985). In Barroso they are called *lameiras*.

22 *Poça* is also used to indicate a earthen dam in a brook or small river in order to store water in the river bed, also called *represa* or *charco*.

23 In Balochistan, Pakistan called *karézes*. These ingenious systems consists of tunnels, interconnecting man-holes, conveying and collecting groundwater over a length of 500 to 3000 m (van Steenbergen 1997)

24 Recent irrigation interventions in Trás-os-Montes are aimed at the (partial) removal of this natural restriction through the construction of dams. The reservoirs behind them will storage excess run-off water from the winter.

25 In Tourém (Lema 1978) and Moimenta da Raia (Martins 1995) the communities themselves installed turbines in local rivers to supply electricity to their villages during some 10 to 20 years before they were connected to the national network in the 1970s.

26 Out of the sample of 22 villages studied in the first inventory study the communal irrigation system was used by all village members only in two villages. However, in some cases up to 50 per cent of the families within the village did not have access to the communal system (Bleumink *et al.* 1992)

27 22 of these villages have been included in an inventory study implemented in 1991/1992 (Bleumink and Kuik 1992). Six other villages have been studied on other occasions.

28 In the neighbouring region of Minho this coincidence is not so marked as in Trás-os-Montes because the population lives more dispersed.

29 For instance, in the area of the village of Corva in Barroso, Prins (1991) measured approximately 50 km of stone walls. To form terraces, in some cases soils have been transported from long distances as is for instance documented by Morgado *et al.* (1994:4) for the village of Barbadães de Cima.

30 The small size and high dispersion of plots in the summer areas is expressed in the saying ‘when the cow is eating from the neighbour’s plot she is shitting in her other neighbour’s plot’ (Bernardo 1983)

31 Thies (1989) noted that the empirical observations were in contrast to the actual theory of furrow irrigation which considers the advance phase as the limiting factor of attaining high application efficiencies. Especially surface storage is not taken in account (see Figure 2.7) determining the infiltrated water depth in short, closed furrows. In addition to this characteristic, infiltration characteristics in space and time vary considerably contrary to the homogeous infiltration characteristics along the furrow , normally assumed in the theory.

32 Although in irrigation circles efficiency is a key concept, it is remarkable how often the value of such a highly time and space contextual parameter is simply assumed, referring to general values mentioned in handbooks. I think that being able to make a reasonable estimate of real irrigation efficiencies on the basis of simple measurements and observation of existing farmer’s irrigation

practices and particularly to interpret irrigation efficiencies in the specific context should become a basic tool in the training of students in irrigation engineering.

33 The large-scale *waribandi* systems of Northwestern India are based on this principle. In these systems water is rationed in proportion to land area but each farmer receives considerably less water than needed to irrigate his whole farm according to maximum crop water requirements. These *warabandi* systems are known to be the most productive and efficient systems in India (Perry 1993). However when the Indian government tried to impose the same water distribution system in other parts of India it led mostly to failures. That shows that a blueprint or a set of particular rules which is successful in a specific context, is not necessarily so in other contexts.

34 In the period that one has the right to irrigate your plot, that person or someone that represents him must be there to receive the water. If one is not there, someone else will use one's water. However it is possible to exchange turns or to make other arrangements.

35 There are various reasons for that. First, the required food production for household needs is diminishing because of smaller household sizes. Second, the production of staple food surplusses (principally potatoes) is less attractive because of lower market prices (influence of competition of Spain and other EU countries). Third, the lack of labour resources leads to an extensification of the cropping pattern. That extensification process can be observed frequently when a household member migrates. Stam (1993:25) in her case study of Vila Cova gives the example of a household in which the youngest daughter was planning to leave the village. This would have as consequence that there would not be enough labour to grow maize on a certain plot and its use would change into permanent meadow.

36 However there are exceptions. In the communal irrigation system of Romainho division of the flow is a normal practice (see Chapter 3.1). Also in other systems flow division in certain periods occurs, e.g. at the start of the summer period when flows are still relatively high (Stam 1993, Prins 1991).

37 In other irrigation contexts there has been conscious rule-making to avoid this head-tail end dichotomy. For instance, in the *zanjeras* (cooperative irrigation societies) in the Philippine province of Ilocos Norte all farmers have been assigned plots at both the head, middle and tail sections of the irrigation systems (Ostrom 1992: 76)

38 Since the massive emigration the maintenance and reproduction of more and more systems is becoming problematic. Where earlier 60 households maintained a system, now 20 households have to do the job.

39 In 6 hill systems in Nepal annual maintenance required 11-32 working days/family (Yoder 1994). In the zanjeras in the Philippine province of Ilocos Norte members are working 40-60 days per member anually in the maintenance of their systems (Yoder 1994:76). Martin *et al.* (1988) showed for Nepalese FMIS that a clear relationship exists between the required resource mobilisation for the maintenance of the system and the nature of the organisational structure. The greater the amount of labour that must be mobilised for the reproduction of the system, the more highly structured and formal the organisation. At the other hand the notorious head vs. tail end problems are avoided because the farmers at the head end are dependent for their water supply on the assistence of the tailenders for the repair and maintenance of the systems, principally the temporary river diversion structures. The construction of permanent headworks, a classical example of external intervention, has frequently disturbed this equilibrium achieving exactly the opposite of its (intended) aim (Lam 1998).

40 In contrast, in many FMIS in other parts of the world proportional rules are in use. That means that the required labor input from water users is roughly proportional to one's share of the resource. In order to enforce the proportional rule, resources have to be expended in counting, recording, and organising various contributions from different uses. In systems with a high maintenance intensity, the gain from the proportional rule may be higher than the administrative costs, while for systems with a

low maintenance intensity (such as the FMIS in Trás-os-Montes) the costs of implementing proportional rules may be higher than potential benefits (Tang *et al.* 1993).

41 Water users that fail to appear are expected to offer wine to the group doing the maintenance work. A similar procedure is mentioned by Yoder (1994: 70) referring to the water-scarce, though easily maintained Thambesi Kulo system in Nepal. 'In this system there have never been cash transactions and the irrigators keep no written records. The irrigators meet just prior to planting the rainy season rice crop and work together to clean the canal. They note which families are not participating in the work and send someone to visit their maize field to harvest a snack for those working. The group monitors compliance or noncompliance to the request for labor to clean the canal and extracts payment, without a written account, from families that miss work'.

42 Another reason could be that until recently the degree of illiteracy within the rural population of Trás-os-Montes was very high so accounting skills were scarce. That is not to say that there are no exceptions or even an increasing tendency to organise the maintenance of the system by means of financial contributions, principally when formal organisations are in some way involved in the irrigation system. For instance in the village of Roriz the maintenance of the rehabilitated system is executed by hired labourers. The money to pay them is collected by the chairman of the parish council. However, not all water users agreed with the payment out of mistrust that the money is wasted or for other reasons, e.g. a woman commented: 'my husband has nothing to do at home, I can send him for the cleaning of the canal'.

43 These officials are known under different names/titles with different competences. In the marvellous irrigation systems on the island of Madeira they are called *juíz de levada* (irrigation judge) and they have powers to send infractors of the rules to the official court (Dias *et al.* 1986). In various villages of Trás-os-Montes these officials are known under different names: *zelador* or *mordomo* in '*terra fria*' systems (Dias *et al.* 1986), *cuidador/couteiro de água* in some 'Barrosa' systems (Morgado 1993). Their competences are normally limited to the monitoring, control and facilitating of the working rules. Carvalho (1996) describes for a village system near Coimbra the competences and functions of a *louvado*. Besides the tasks of monitoring and control of the water distribution rules the competences of this official goes a step further: in times of serious water scarcity the *louvado* has the power to intervene directly in the water distribution in order to save crops which are wilting. The clash between the customary rules and the ad-hoc changes introduced by the *louvado* is sometimes a new source of conflicts.

44 The development of local administration and its relations with the State is a very complex history in rural Portugal. In the past the parish was both an ecclesiastical and a secular unit. With the end of the monarchy in 1910 the parish lost its ecclesiastical character. Parallel to the increase of public investment in the villages after 1911 but principally since the 1974 'Carnation' Revolution, the parishes have lost autonomy in relation to the municipalities (*concelho*) and the State.

In the past communal affairs (for instance regulation of the use of the *baldios*) and investments were handled by communal councils (*conselho do povo*) at village or hamlet level, consisting of the representatives of all households or *vizinhos* (neighbours). Communal and public infrastructure was fundamentally created and maintained on the basis of labour investments of the *vizinhos*. Additional financial means were acquired by e.g. selling of baldio plots, the yearly auctioning of a part of the irrigation water, communal meadows etc. The *freguesias* in that time were little more than administrative units serving as links between the communal councils and the municipality. The communal councils (*conselho do povo*) controlled the *junta de freguesia* as the executive body to implement their decisions.

In time the communal institution eroded more and more and the power came increasingly in the hands of the executive , the *Junta*. In spite of the legal creation of the *assembleia de freguesia* as the controlling organ at the local level since 1979 (Ferreira de Silva 1994), the *junta* became more part of a central hierarchy, funcioning more as an extension of the administrative hierarchy than a body of the local autonomy.

45 Even within the mere technical paradigm I have the impression that in ‘modern’ irrigation schemes and projects the hydrological potential of the water resources is frequently ignored or underestimated. To give only some examples from my professional experience: In the province of Gaza in Mozambique nearly all the available water in the big storage reservoir of Massingir was, in spite of the advertisements of irrigation engineers in the province, used up at the end of 1982 in the first irrigation of 25,000 ha of rice in the irrigation scheme of Chokwé. For further irrigation of the rice crop there was hardly any water. One year later, the then Minister of Agriculture stated in a meeting to prepare the next agricultural campaign that the ‘drought’ was principally located in the brains of the engineers and took personally the decision to do the same as in the year before but he had the luck (of ‘Russian roulette’) that from December 1983 on, it started to rain torrentially in the watershed of the river Limpopo and catchment area of the dam. Another example, also from Mozambique: in the province of Zambezia a glossy project proposal was made by an Italian firm for the irrigation of 20,000 ha of rice. Irrigation canals have been projected with a capacity of 20 m^3/s without any hydrological analysis of the water source. After a short check it was discovered that the water source, a small river, yielded with pain a maximum streamflow of 1 m^3/s. The same negligence of hydrological factors I met in the MRT irrigation intervention programme in Trás-os-Montes (see Chapter 6).

46 Water allocation and water distribution are often used interchangeably in the irrigation literature to describe the delivery of water (Martin and Yoder 1988a). Indeed, it is sometimes difficult to make a clear distinction between allocation and distribution. In some Trás-os-Montes systems allocation rules could be so detailed that water distribution is for a considerable part already determined (see Chapter 3.1, the Romainho irrigation system). Portela (1988:208) describes the water allocation schedule in the studied system as a basic guideline or framework that is consulted only if a major dispute occurs. Deviations from this schedule could be functional because they enhance the operational flexibility of the system. He adds however that ‘one may foresee that any major proposal for changing the irrigation system would raise fears of disruption not only of the ideal pattern (i.e water allocation, AvdD) but also of the real deviations (i.e. water distribution, AvdD)’.

47 Very little is known about the origin and history of the FMIS in Portugal. Carvalho (1996) made an interesting study about the changes that occurred in a FMIS near Coimbra since approximately 1800. The most important change was the increase of the irrigated area downstream of the source and the appointment of irrigation officials (*louvados*). These were very disputed questions involving the upstream water users, local government and the judiciary. The increase of the irrigated area was realised but the upstream water users near the source maintained preferential water rights. In the downstream area *louvados* were appointed but the users refused to elect or appoint these officials in the upstream area. Although these questions were solved in 1868 they came again to the surface in 1911 after the establishment of the Republic and in 1974 after the Carnation revolution. During 1975 two *louvados* have been appointed for the upstream areas but their actuation generated so many conflicts that they had to step down. Carvalho concluded that in this system basically the same principles of allocation and distribution are operating more than a century. It shows the robustness of these institutions.

48 Portela (1988: 203) mentions that the water allocation of the ‘Ribeiro Frio’ system in a village located in the municipality of Vinhais had its origine probably at about 1909. According to the elderly he spoke with, the local priest and two other men designed the plan to avoid major conflicts among water users.

49 Coward (1985) refers to this investment in irrigation facilities as the creation of hydraulic property. The participation of farmers in the creation of hydraulic property (through work, money contributions

and other resources) establishes internal property relations. These relations are translated in individual water rights and obligations in the reproduction of the system.

Could water rights in peasant societies have been established in another way? In the last few years, I visited rehabilitated FMIS in the Philippines and Ecuador, and suddenly realised the scope and significance of such an abstract concept as the creation of hydraulic property. Farmers and officials told me under which circumstances the construction and rehabilitation works had been implemented. Access to the sites was very difficult. All construction materials had been transported by labour force, bags of cement (50 kg /bag) carried on one's back walking along very small paths, running for miles, an abyss at one side and/or very steep slopes where one has to 'walk' on one's knees. Some serious accidents occurred during construction. After visiting the construction sites I understand a little bit more what is at stake in irrigation development in these zones and the importance of the congruence between costs and benefits.

50 Data from Table 2.6, principally based on findings from the first inventory study (Bleumink *et al.* 1992), suggests that the functioning of Mountain systems is generally more complex than High Valley systems: in the sample all multi-level systems are mountain systems with a higher water availability. The results of the second inventory study (Malta *et al.* 1993) show that plot-based water allocation systems are underrepresented in the Table. Further, flow dividing occurs more frequently than found in the first inventory study.

51 This is different from the normal time shares whose dispersion corresponds to the fragmentation of plots.

52 The same behaviour has been mentioned by Carvalho (1996:190) in a FMIS near Coimbra.

53 The local expression for this 'free-to-take' style of water use is *'a pilha'* which literally means plundering.

54 The local expressions are *(estar) à vez* which literally means 'waiting untill the opportunity presents itself' or *torna torna*. A used tactic is for instance to hide oneself at night behind a tree while another farmer directs (*torna*) the water on his meadow. Then after this farmer leaves the other one redirects (*torna*) the water on his own meadow.

55 Passing the night nearby the water sources was also mentioned as a normal practice by Bernardo (1983).

56 Other minor ones are allocation on basis of flow division (see Chapter 3.1) and on basis of volume e.g. one whole or part of a *poçada* (one reservoir full independent of the time it takes to fill it).

57 As will be shown in the case study of the Vila Cova system (Chapter 3.2), water use can be made more flexible by combining water of different sources and by using storage facilities at plot level.

58 In a similar way Martin and Yoder (1988a) show for FMIS in Nepal that the principle of water allocation has important implications for the efficiency of water use and the expansion of irrigated areas. They compared a system in which water is allocated in proportion to the irrigated area with a system water is allocated by purchased shares (property rights in water are separate from ownership of land). They found that the last allocation principle allowed for a greater expansion of area irrigated and equity of access to irrigation.

59 Reservoirs become more and more crucial as infrastructurural elements in the degree that water availability in irrigation schemes decreases. For instance, an unworkable streamflow of 1 l/s could be transformed by means of a reservoir to a manageable field flow of e.g. 4 l/s (although the outflow of a reservoir is diminishing in the degree that the reservoir empties).

60 These time shares normally do not exceed 24 hours. With the range of continuous flows in which reservoirs are normally used (0.1-5 l/s) the storage capacity of the reservoirs is in the range of only a few m^3 to some hundreds of m^3.

61 A special form is the double reservoir with two storage elements which increases in some degree the flexibility of water distribution and application. The first reservoir serves to store the incoming water of the source. At the end of the time share, the water stored in this element is transferred to the second reservoir from which irrigation takes place, independently of the inflow to the first reservoir. In Chapter 3.1, the detailed operation of the double reservoir of Romainho will be shown.

62 Less common is that irrigated and rainfed (rye) plots are alternated from year to year (in Galegos da Serra); that in one year the water right accrues to one household, the other year to another household (e.g. in the case of 2 heirs). The same biannual alternation is mentioned by Strijker (1992) for some irrigation systems in Reboreda.

63 In the case of small groups (2 or 3 water users) stored water is sometimes divided between the water users by measuring the water level in the reservoir with a stick.

64 Sometimes rules and mechanisms are very simple. For instance, in the communal irrigation system of Sesmil water allocation consists of a combination of long (10-18 hours) and short (1-5 hours) time shares. They are all sequentially stored in a double reservoir. Through a specific sequence of short and long time shares in which long time shares are all located in the night (the night water will be used for irrigation in the morning hours) night irrigation is actually avoided (Pinto Marques 1994).

65 Compensating mechanisms are not limited to irrigation but are ingrained in all communal undertakings. Portela (1986: 10,11) gives an example of cooperative labour related to the threshing of rye (with a stationary threshing-machine), until the recent past a very labour intensive activity which could only be organised by joining many households. The sequence or order in which the threshing in the village was realised is not arbitrary. All households want to be the first to tresh their rye but ‘to avoid that some laugh at the others’ a principle of rotation of the threshing-machine is established. The household which starts threshing in a certain year will be the last to thresh in the next year. By this mechanism the risks that rye-stacks will be affected by rain and fire will be more or less randomly distributed among the households.

66 In 17 cases water was exchanged for labour, in two cases for wine and in one case water for animal traction

67 In all irrigation systems one has to use one’s water right in one way or another to secure it. This is reflected in the proverb: *o uso é uma lei por estas paragens* which signifies ‘the use is a law in these places’ (Peixoto dos Santos 1995) or *o costume faz lei* which means ‘the custom makes law’ (Bernardo 1983).

68 An exhaustive inventory of agronomic practices in Trás-os-Montes related to irrigation is presented in Malta *et al.* (1993). Another telling example of skill-oriented technology is the intensification path of small dairy farmers in the High Valleys, as is excellently described and analysed by Baptista and Portela (1990). Very limited land and water resources are compensated for by a labour-intensive and very finely regulated cropping practices (crop rotations, relay planting, adjustment of fodder production to fodder needs, risk-attenuating practices, use of irrigation water etc.) in order to produce enough fodder for the two or three milch cows these farmer households normally own.

69 But the proverb says: *Fevereiro quente traz o diabo no ventre* (Lit. A warm February is pregnant with the devil) which point to the danger of frosts.

70 The contour ditch irrigation method, normally used for meadows, is technically inefficient involving much application (run-off and percolation) losses. However, in the winter period this is not a problem because of an ample water availability but in the summer available irrigation water is a serious constraint.

71 Prins (1991) stated that in Corva a number of households was seriously hindered in the expansion of their farms because a small number of households own the large majority of land and water resources. This group experienced the division of water rights as unfair and wished to change it. However they

said it proved impossible to alter the situation. Many times they had tried to discuss it with the other farmers but without any success. Bleumink *et al*. (1991c) told a similar story about the irrigation system of Vilalva.

72 It was to be expected that social capital reflected in the functioning of the old system was destroyed. But it is remarkable that social capital has been so easily restored when the system was rehabilitated. That shows that the deeper sources of social capital in the irrigation systems is embedded in the village community, i.e. the way villagers relate to each other in multiple ways (e.g. family ties, labour exchange, other communal institutions).

73 The construction of these traditional sources, particularly galleries (*minas*, lit. mines) needed specific skills, was very labour intensive and not without danger. Mostly wandering artisans (*mineiros)* from the neighbouring region of Minho (the region within Portugal where traditional irrigation has been most developed) were contracted to supervise the construction of these *minas*. According to old farmers the construction of galleries was already in the past an expensive investment as they say: 'to make a *mine* you need another mine of money'. Nowadays, *minas* are hardly constructed anymore because of the much higher labour costs. As people say: 'to construct a *mina* you can make eight to nine tubewells'.

74 A local rule states that exploration of water resources on own land is allowed if it is realised on more than 50 m from collective or public water sources.

75 This technology has superseded traditional technologies as the construction of shallow wells and galleries. 'If water is your problem, the tubewell is your solution' is one of the publicity slogans on the local radios (Carvalho 1991). In 1992 there were as many as 5 entrepreneurs constructing tubewells in the city of Chaves only.

76 SCOM: *Sala Collectiva de Ordenha Mecanica*.

foto

3 Farmer-Managed Irrigation Systems: Two Case Studies

This chapter presents two case studies of Farmer-Managed Irrigation Systems in Trás-os-Montes. In these case studies the most relevant aspects of the functioning of farmer-managed irrigation schemes in Trás-os-Montes, as discussed in Chapter 2, will be highlighted. I will focus on water allocation and distribution which constitute core activities[1] in irrigation systems and determine the performance and outcomes of irrigation practices. In the case study of the irrigation system of Romainho I will concentrate on water allocation, in the case study of the Vila Cova system on water distribution. The case studies are specially intended to demonstrate the locally constructed coherence of the elements that have been discussed relatively in isolation from each other in the previous chapter.

The FMIS of Romainho and Vila Cova are not representative for the majority of FMIS in Trás-os-Montes. The functioning of the latter is generally more simple, particularly those located in the High Valleys[2]. Romainho and Vila Cova are complex, particular cases but exactly for that reason they are highly illustrative of the functioning of FMIS in Trás-os-Montes in general.

I will particularly focus on the internal coherence and the logic underlying the functioning of the systems. Although particular rules are different in every specific system, the outcome of (combinations of) these rules in most systems is the creation of equal operational conditions for the water users with respect to variation of flows, timing of irrigation turns etc. as discussed in Chapter 2.3. In this way the users obtain the amount of water to which they are entitled. This underlying principle is very pronounced in the systems of Vila Cova and Romainho, as will be shown in this chapter.

The two cases display some similarities: The irrigation systems are both Mountain systems with relatively large discharges of their sources compared to many other systems (see Table 2.7). They are communal irrigation systems (*Rego de Povo*) and each is by far the most important system in the respective village. The systems operate both in contexts characterised by shortage of labour: in Romainho many emigrated while in Vila Cova pluriactivity dominates.

An important difference in operation between the two systems is the use of a system reservoir in Romainho while water is running continuously, day and night, in the canals of Vila Cova.

The decreasing outflow of a reservoir implies that rules are needed to distribute and to even out in some way the variation of outflow over the individual users.

In the case study of the communal irrigation system of Romainho I will focus on the very complex water allocation pattern. However, in this case it is difficult to separate allocation from water distribution. Allocation rules are so detailed that they also determine to a great extent how the water will be physically distributed. Presenting the water allocation schedule in all its details may appear boring but it is a fascinating story, because it tells how water rights have developed in time and how its pattern became always more complex and detailed. Nearly all the allocation principles and some specific allocation rules (proportional flow division, parallel allocation patterns and meadow irrigation at Sundays, use of excess water from meadow irrigation) are present at more levels. In this respect we find here the 'nested enterprises' Ostrom refers to (see Box 1.1). This actual pattern is the outcome of a long historical process. In my opinion, Romainho now is a clear example of a tendency towards involution. The users are not crafting new rules (respecting existent water rights) leading to a qualitative transformation of the pattern that is better adapted to the actual context. Although the potential for change exists[3], it is an open question if this will materialise.

In the case study of the communal irrigation system of Vila Cova I will focus on the complex conversion of water allocation in water distribution and the rules-in-use to realise this conversion. In all systems, the allocation of water forms the basis for water distribution within the systems but detailed allocation of water in itself does not automatically result in distribution. Working rules are necessary to convert abstract water rights into actual flows to the different parts of the irrigation area during determined periods of time.

In Chapter 7 I will come back to Vila Cova and show that even in such a complex and balanced system meaningful (physical) improvements can be designed from the perspective of the adaptation to a changed context and by building further on its actual functioning and underlying logic.

3.1 A complex water allocation schedule: The case of Romainho[4]

Romainho: the Setting

Romainho (for location, see Figure 2.2, village # 13) is one of the three hamlets of the parish of Covas de Barroso, located in the municipality of Boticas which forms the southern part of Barroso. The parish is part of an ecological sub-zone called 'Baixo Barrosa Occidental'. Frosts occur from October until the beginning of May with some 70 frost days a year. Mean annual temperatures are slightly higher than 12^{o}C. Annual mean humidity is about 80 per cent. Mean annual precipitation amounts to about 1300 mm, 65 per cent of which falls in the period of November till March. Pan evaporation has an average annual value of about 1000 mm (PDAR 1992).

The main part of the parish is situated at 550-950 m altitude, with gently sloping land as well as rather steep slopes. Romainho lies at about 635 m. The basic rocks in the region are granites and schists. Granite and the resulting sandy soils can be found mainly higher on the hills, while schists have composed silt and clay soils in the valleys. A lot of brown soils can be observed, a result of prolonged manuring.

The hamlet has 88 permanent habitants and about 30 more emigrants have their house there. They form part of in total 33 households. Emigration has been extremely high. From 1950 to 1981, the parish of Covas de Barroso had an out-migration of over 60 per cent. There is also much temporary migration. It has profoundly affected many aspects of life and local society. This is clearly shown in the composition of the population. Especially people in the working age between 25 and 45 years, men more than women, are under-represented in the parish (PDAR 1992).

The lack of labour causes many farmers to change their cropping pattern. Labour-intensive crops like potatoes are being replaced by (permanent) meadows.

Agriculture

Agriculture in the agroecological sub-zone of 'Baixo Barroso Ocidental' is characterised by a transition from permanent pastures as is characteristic for the mountain areas of Trás-os-Montes to an annual crop-meadow rotation as practised in the neighbouring region of Minho. Plots are small and scattered. The main irrigated crop is pasture (permanent and annual) both in summer and in winter. In summer, irrigated crops are potatoes, maize and a small amount of horticulture. Maize (for the grains) is grown in Covas de Barroso on 15-20 per cent of the cultivated area (SAU). In Romainho no clear cultivation pattern exists, people say that they let the choice of crop depend on (market) demand each year, in most cases on the fodder needed for the cattle they have at that moment.

In Covas de Barroso over 40 per cent of the SAU consists of permanent pastures (PDAR 1992). The main source of agricultural income in the village is the selling of meat calves (6-8 months).

Vineyards for wine can be found on about 4 per cent of the SAU (PDAR 1992). Vines are being used to indicate the borders of the parcels, the so-called *Vinha bordura*, a typical feature of the Minho landscape.

In Romainho, close to the village at the gentle sloping land, gardens with horticultural crops like onion, tomato, beans and paprika can be found. Further downhill the slopes are too steep and forests with pines as well as fruit trees and olive trees for one's own consumption are grown.

Meadows generally are situated uphill, with ancient permanent pastures for grazing close to the tops of the mountains. As these pastures are mostly composed by the original plant species and receive only some incidental manure from grazing cows, sheep or goats, the vegetation often closely resembles the *baldios*[5]. At these fields, shrubs and heather are gathered to serve as stable material. Downhill, where more water is available, the meadows are used only for green fodder and hay-making, they are never being grazed. Intermediate forms of meadows exist as well.

Irrigation in Romainho is principally being applied to meadows, potatoes and maize but in small quantities to horticultural crops as well.

Irrigation sources

A brook bordering the territory of Romainho, called the *Corgo de Lamais* is by far the most important water source used for irrigation. Streamflow is permanent but decreases sharply in the summer. In 1992, discharges have been measured between approximately 44 l/s at the end of June and 13 l/s at the end of July. The '*Corgo dos Lamais*' is the source for the communal irrigation system which serves almost all farmers and the major part of the cultivated area. The area irrigated by this system is approximately 30 hectares.

Apart from the main communal system, some 30 small reservoirs, *poças*, exist. These reservoirs are fed by streams, springs or horizontal galleries (*minas*) excavated in the mountains. Combinations of different sources in the same reservoir are possible as well. Most of these water sources are private but some of them are shared with up to 15 people. When a certain source is being used by a group of people, a separate allocation schedule exists for that source. In some cases this schedule is used throughout the year with only slight deviations possible. In other cases a more flexible situation exists. Especially with a restricted group of water users, a lot of ad hoc arrangements are made. Water allocation in the winter is mostly based on the *a vez* rule (see Chapter 2.4). In the summer the scarce water is allocated according to time shares or a rotation sequence of fixed plots. Usually the summer allocation schedule starts at the 24^{th} of July or on the day the main system starts.

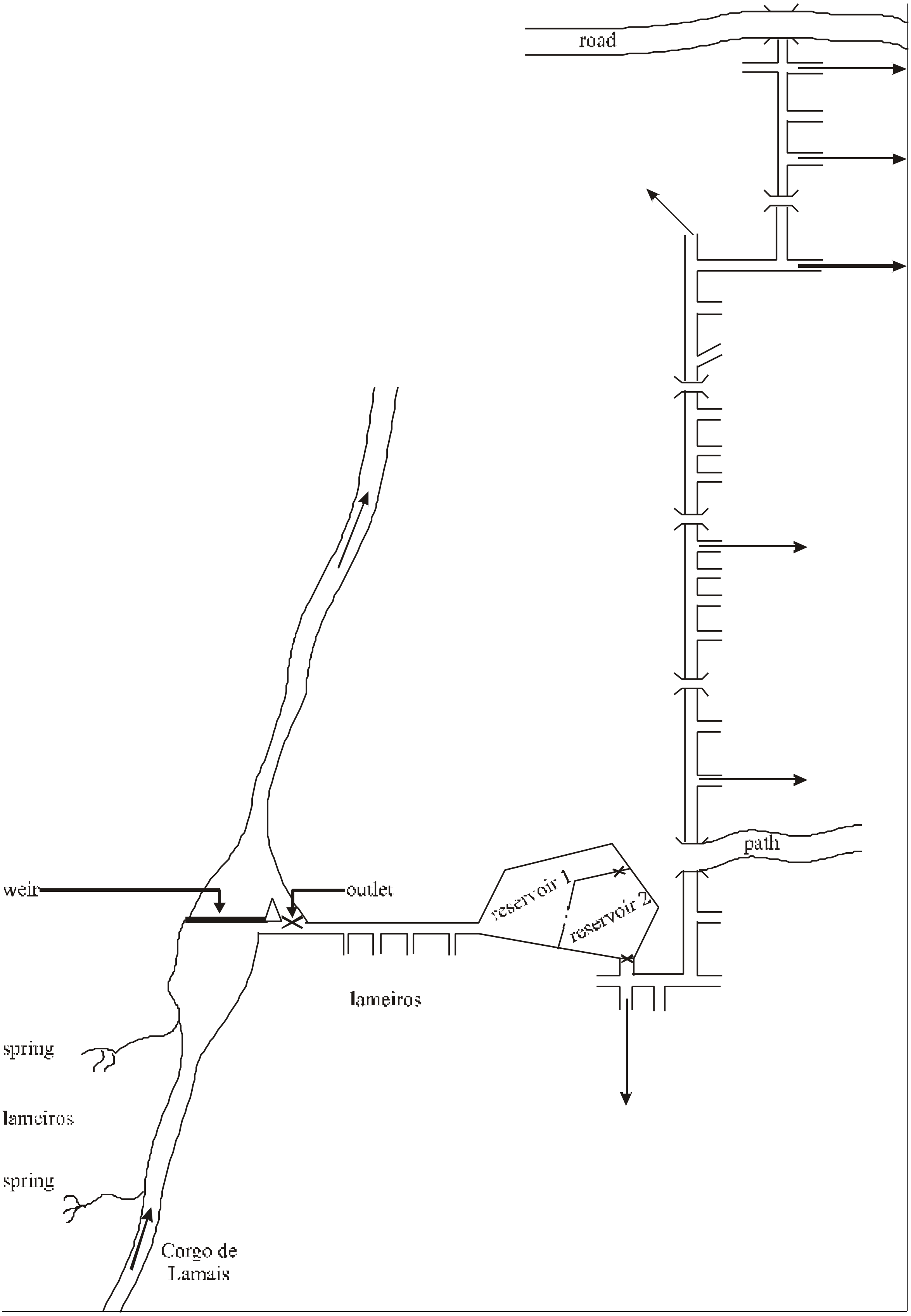
The communal irrigation system

The origin of the communal irrigation system in Romainho is unknown but its history goes back at least to 1860. That year is marked on a stone near the canal. Some villagers stated that the stone was placed there after a reconstruction of the source. Figure 3.1 shows a sketch of the communal irrigation system and its layout.

Physical infrastructure

The system consists of a concrete diversion weir in the '*Corgo de Lamais*', which diverts the water to a long (500 m) concrete main canal. From this canal five outlets go to earthen, rather steep canals. The main canal ends in two concrete reservoirs (named *poças).* From these reservoirs the water follows the main, concrete canal to the village. In this canal 23 division structures lead the water to an extensive network of earthen field canals. These canals often consist of stone beds or roadsides.

Figure 3.1 Lay-out of the communal irrigation system of Romainho (sketch, not on scale)



The weir diverts all the water of the stream into the canal. Only with very high discharges the water crosses the weir. Two meters from the beginning of the canal an outlet exists that can lead the water back into the stream[6]. This outlet is equipped with a slide with screw regulation. The two reservoirs have the same type of regulation. Other water division structures are constituted by iron slides that fit into grooves, both in the canal and in the field inlets. When the water discharge is high, the iron slides often need to be kept in place with stones. Not one structure is locked with a key, everyone can open and close the in- and outlets according to the allocation schedule. In the earthen canals the water is divided by means of stones, as is the case when a proportional division of the water is required. For diverting flows, the earthen canals are being closed with bunches of weeds and soil.

The actual physical infrastructure is the result of an MRT intervention. In the framework of the Trás-os-Montes Integrated Rural Development Project (PDRITM) the original system was improved in 1990. The large amount of water losses through infiltration in canals and reservoirs has been cited as main reason for the intervention (GATAT 1987). The existing infrastructure simply has been used as the layout. The rustic dam has been replaced by a concrete diversion weir and the two existing earthen reservoirs have been lined. 1,730 meters of earthen canals have also been lined. Field inlet structures have been constructed at the same original sites. The water right system has not been taken in account, nor has it been changed. At the time of the intervention an irrigator's council (JAR[7]) was constituted. People contributed to the costs of the improvement intervention in money or working days more or less in proportion to their water rights.

Operation of the system

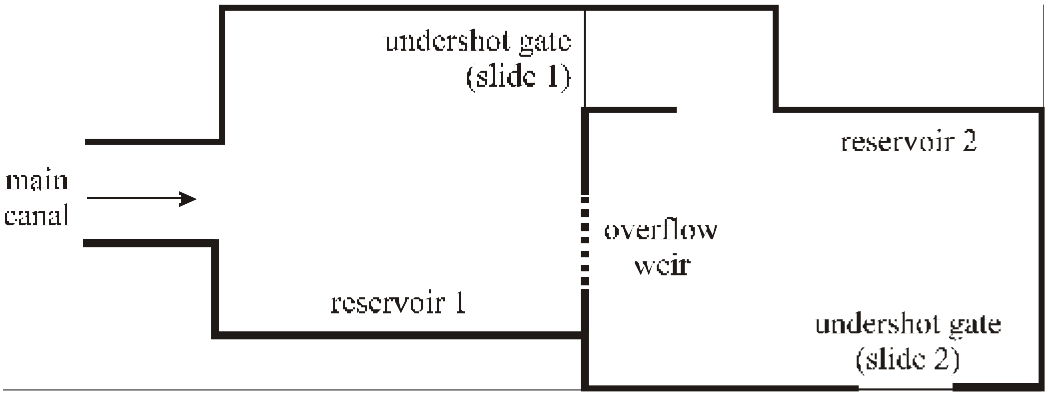
On Sundays the water of the stream may be used on plots upstream of the weir or on plots between the weir and the reservoirs. At Sunday evenings the individual (or member of a group) that has the first irrigation turn on Monday, has to 'join the water' upstream. This means that two springs are led to the 'Corgo de Lamais' instead of the nearby fields. Also the inlets to contour channels supplied by the stream are closed. At the weir the entire flow is then led into the main canal of Romainho.

The operation of the reservoirs

The two interconnected reservoirs constitute a double reservoir. One reservoir stores the incoming flow when at the same time the other reservoir is used for irrigation. The operation of this double reservoir is described below.

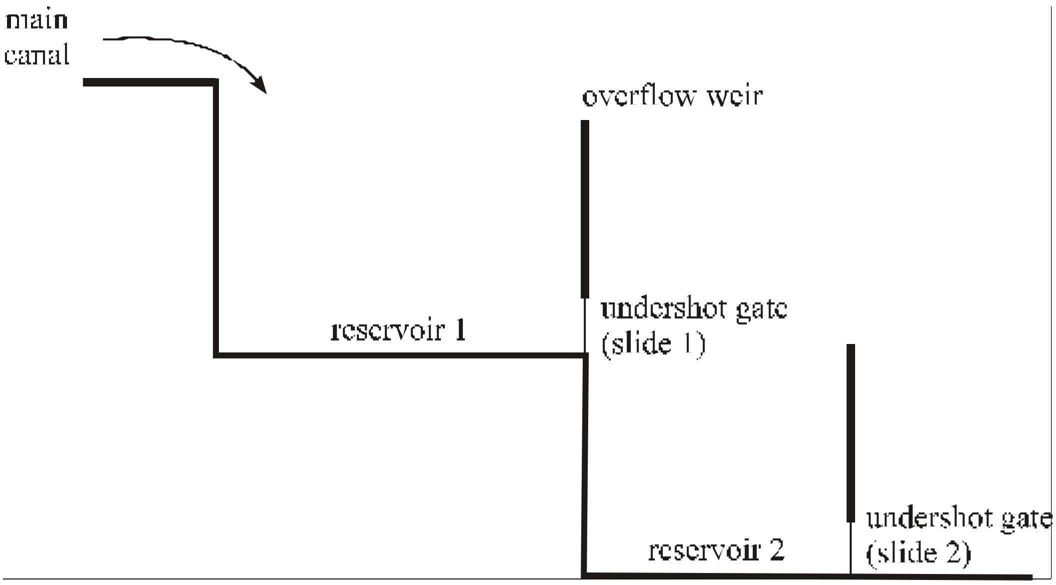
In Figure 3.2 a top view of the double reservoir is sketched. The water as diverted by the weir enters the first reservoir. The water can enter the second reservoir by the undershot gate which is equipped with a slide (slide 1). When the undershot gate is closed and reservoir 1 is full the water passes an overflow weir into reservoir 2. The only outlet of the second reservoir consists of an undershot structure (slide 2) that directs the water into the main canal.

Figure 3.2 Top view of Double Reservoir



The two reservoirs do not have the same floor level. Figure 3.3 shows a cross section of the double reservoir.

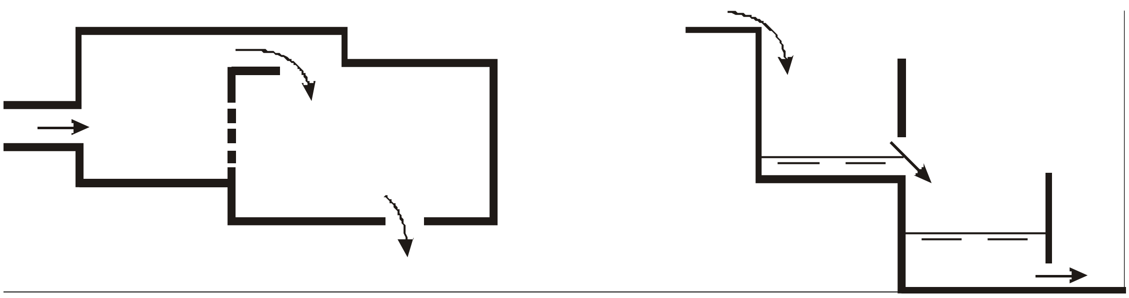
Figure 3.3 Cross-section of Double Reservoir



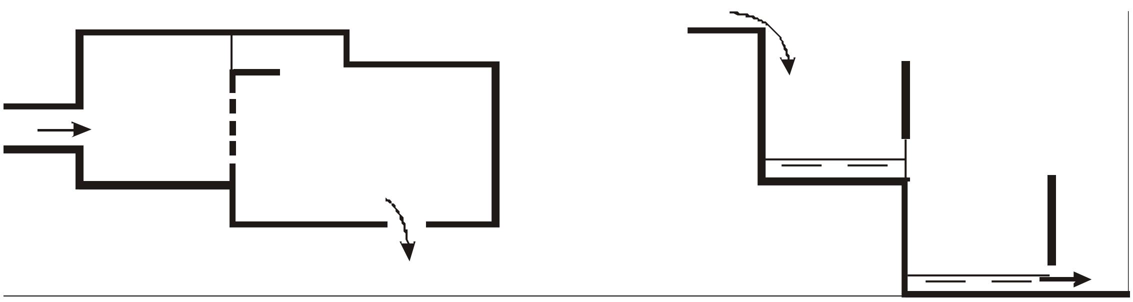
On any day, when it is of someone's (person or group) turn to irrigate, say irrigator Y, he first closes reservoir 1 (i.e. the undershot gate to reservoir 2) at his fixed hour, or arranges someone to do that. These hours have been fixed by sun-marks (*relógio de sol*) in rocks alongside the canal, or, in case of the night turn, the appearance of the evening star. Though today everybody is using watches, now and then the starting hours of an irrigation turn are checked with the marks. After closing reservoir 1, irrigator Y has to wait until the second reservoir is totally empty as this water still belongs to the present irrigator (or group), say X. When reservoir 2 is empty, slide 2 will be closed. The detailed operation sequence of the double reservoir is illustrated in Box 3.1.

Box 3.1 The operational sequence of the double reservoir

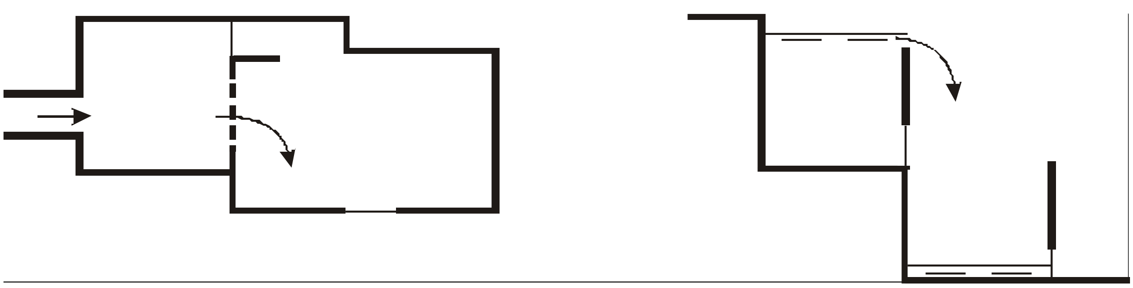
The operation of the double reservoir is illustrated in the following sketches representing a sequence in time.



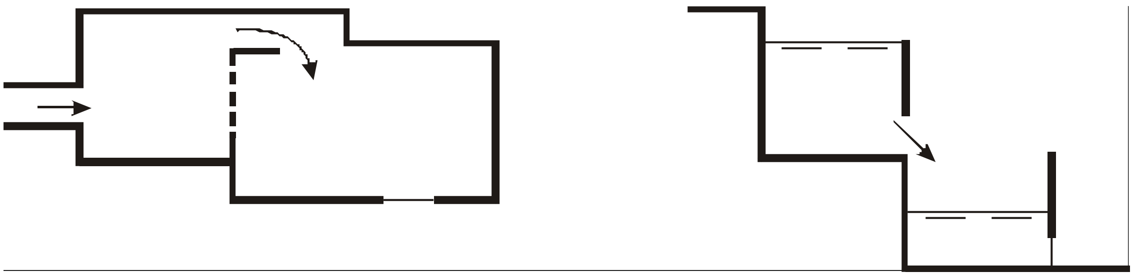
a. Arriving at the double reservoir, irrigator Y (person or representing a group) finds reservoir 1 open so that the flow from the upstream canal crosses into reservoir 1 into reservoir 2 that still contains water with which person (or group) X is irrigating



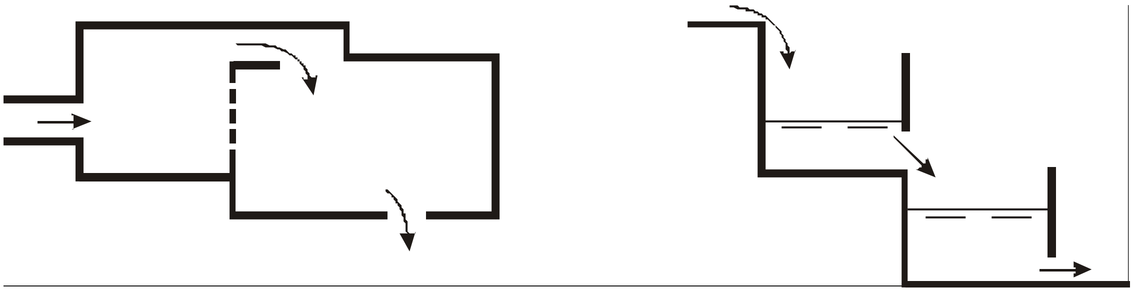
b. When the time slot for irrigator Y starts he closes slide 1. The incoming canal water will be stored in reservoir 1. The water in reservoir 2 is emptying and belongs to the preceding irrigator X.



c. When reservoir 2 is empty, slide 2 is closed. Irrigator Y then can leave the site to do other works. The water from reservoir 1 that will flow over the weir when it is full, will then be stored in reservoir 2.



d. Some time (1 to 2 hours) before the end of time slot, irrigator Y returns to open slide 1. The stored water in reservoir 1 is then flowing into reservoir 2.



e. Irrigator opens slide 2 and the water from reservoir 2 is used to irrigate. The cycle will start again when it is the turn of irrigator Z.

In case some people have to irrigate at the same time, they make an ad hoc informal arrangement. Then only one person has to go to the reservoirs. He also divides the water proportionally when necessary according to the *rol*. With plot rotation it is normally the one that will irrigate first who operates the system.

When both reservoirs are closed, irrigator Y can check the canal. He walks along the canal, which is dry by then and closes as accurately as possible outlets that should not receive water in the next turn.

When the two reservoirs are nearly full, irrigator Y first opens the outlet of the first reservoir, to direct all his water into the second reservoir. From the second reservoir the irrigation is then actually being performed. The outlet of reservoir 2 is opened as far as possible without overflowing of the concrete canal. In this way a rather high discharge can be obtained, up to about 35 l/s. This water subsequently can be used by one person, rotated among a group of people or plots or divided proportionally. For the proportional division of water no hydraulic structures are used. People realise the required division by visual estimation using stones or wooden sticks.

Water allocation

The water is allocated according to different principles in summer and in winter. In the 'winter' period (30 September- 23 June) the discharge of the *Corgo de Lamais* is used by the people of Romainho and also by downstream users. It is normal practice for the outlet from the canal to the stream to be opened a little. Then a reasonable discharge can still be used downstream.

In the wintertime everybody in the village has access to the water for all plots. The *a vez* rule is being practised: as long as someone is irrigating, (s)he will be respected and other water users will have to wait for their turn.

In summer, from the 24th of June until the 29th of September, the approximately 47 users[8] of the communal irrigation system of Romainho have the right to the whole discharge of the *Corgo de Lamais*. During this period a very complex water allocation schedule exists. These complex schedules are not uncommon in Trás-os-Montes, particularly in the Mountainous zones like Barroso.

Though most people know their irrigation turns by heart, some of them possess a hand-written paper with their turns. Some people, especially when they have turns on different days, make a new list every year based on the last one. This makes sense because some turns change each irrigation interval and/or each year. The president of the irrigator's council (JAR) is helping others. Therefore he has a complete, if not very clear, account of the total schedule[9]. This has been made some years ago to calculate the contribution of each irrigator to the improvement.

The water allocation schedule, the so-called *rol*, distinguishes between nine days or *dias*, with their own specific allocation pattern. These days have names and rotate among the days of the week from Monday to Saturday. Each day (24 hours) has 3 or 4 periods, *horas* (literally hours) or *poçadas*[10]. Before watches were used, the start and the end of the different periods during the day have been marked by shadows of the sun casted on marks in rocks near the reservoirs. The start of the night period coincided with the appearance of the evening star, Venus[11].

In each *poçada* the water may belong to one person, but also may be divided proportionally (in *regos*) and/or be rotated among specific located plots of 4 to 23 persons (*roda*). Each day period has a name and a fixed schedule of its own. Some special arrangements exist in which people only have irrigation turns on one out of two (*vez sim, vez não*) or one out of two years (*ano sim, ano não*).

Another possibility is that the water is allocated to the meadows upstream of the weir. The excess water (*corredias*) is then distributed again according to a schedule. In two cases the water is first assigned to a certain person and only after he has finished the irrigation, others may use the water. On Sundays, the water goes to the outlets between the weir and the reservoirs. Though the fields irrigated by these outlets may also be included in the nine-day allocation schedule.

In Romainho water rights are historically linked to a certain plot of land, but assigned to a person. This means that the rights belong to a certain plot of land, but actually are being owned by a person; it is this person's name that is on the allocation schedule, not his land. People know for themselves which plot is meant at what time. With rotation among specific located plots (plot-based allocation, see Chapter 2.4) the water can only be applied to these plots and not to others. Also crop choice is restricted: meadows cannot be irrigated. In other allocation principles more flexibility is possible. Flow division allows an irrigator to apply the water to other plots than it was originally meant for. When a whole *poçada* of water is assigned to one water user, much more freedom exists to apply the water according to farmer's preferences.

The water distribution schedule in Romainho has different allocation principles at different levels which are shown in the complete allocation schedule detailed below.

Water allocation schedule of the Romainho communal system

1st level

The water allocation system in Romainho consists at a first level of time shares: a rotation over nine days (*dias*) between different groups of water users. The names of the days correspond with specific locations and water users can have rights in more than one of those. The sequence of these days is different for even and odd years. Sundays are not counted in the nine-day period. A parallel allocation pattern exists on Sundays: water is allocated to the meadows between the weir and the double reservoir. An overview of the days follows in Table 3.1.

From this table it can be derived that two irrigation turns take exactly three weeks. This corresponds to a number of 9 complete irrigation turns in the summer (in the period from the 24th of June until the 29th of September).

2nd level

The day periods *(horas* or *poçadas)* could be considered as time shares at a second level. Some days have 4 periods, others have 3 periods. Information about the length of the periods is contradictory: fixed 6 to 8 hours vs. a variable length dependent on the place of the period in the day. An effect of a variable length of the day periods could be for instance that night irrigation is avoided. Also the changes of the day periods from turn to turn is not known, probably the place of the day periods rotates each irrigation interval[12] (of 9 days). However it may be, the division into day periods creates the possibility to more or less equal operating conditions for the water users, e.g. to guarantee that it is not always the same persons that have their irrigation turns at night or that the irrigation turns for the users are on average evenly distributed over the day in a summer period.

Table 3.1 1st level allocation

Even years *First turn*		*Odd years* *First turn*
1. DIA DO COSTA 2. DIA DO PACO 3. DIA DE JOANA AFONSO 4. DIA DE TRAVESSA 5. DIA DO LABANCO 6. DIA DO VIACOVA	Monday Tuesday Wednesday Thursday Friday Saturday	DIA DE FUNDO DE VILA DIA DE VIACOVA DIA DO LABANCO DIA DO COSTA DIA DO PACO DIA DE JOANA AFONSO
Meadows between the weir and the reservoirs	Sunday	Meadows
7. DIA DE FUNDO DE VILA 8. DIA DOS MUITOS 9. DIA DA ACRESCENTADA	Monday Tuesday Wednesday	DIA DE TRAVESSA DIA DOS MUITOS DIA DA ACRESCENTADA
Second turn		*Second turn*
1. DIA DO COSTA 2. DIA DO PACO 3. DIA DE JOANA AFONSO	Thursday Friday Saturday	DIA DE FUNDO DE VILA DIA DE VIACOVA etc.
Meadows	Sunday	
4. DIA DE TRAVESSA 5. DIA DO LABANCO 6. DIA DO VIACOVA 7. DIA DE FUNDO DE VILA 8. DIA DOS MUITOS 9. DIA DA ACRESCENTADA	Monday Tuesday Wednesday Thursday Friday Saturday	
Meadows	Sunday	
Third turn		
1. DIA DO COSTA	Monday	Etc.

A whole day period may belong to one person, but mostly the water is shared, so more levels in water allocation can be distinguished. These levels will be indicated by a value in the tables. The water allocation principle with an capital letter, respectively:

A: time shares

B: plot based

C: proportional flow division

D: other, e.g. dependent on location.

For instance, the indication (4B) means a plot-based allocation at the 4th level.

The detailed water allocation schedule[13] is written down in the following pages.

DIA DA COSTA (1)		
HORA DA COSTA (2)	*HORA DA COSTA DE CIMA*(2)	*HORA DA COSTA DE BAIXO* (2)
4 regos (3C) *1. JBE* *1. vez sim* (this or even turn) (4C) *1/2 FP* *½ MFP* ------------------------- *vez não* (next or odd turn) *MM* *2. roda* (wheel) (4B) *6 pessoas/* (plots) *DP* *Asm* *OSG* *DPL* *FPL* *FP*	***Lameiros em cima açude*** *(3D)* (meadows upstream of the weir) *(4A) 1/2 MAC* *½* (5) *JdB* *herdeiros Albina* ***corredias*** (excess or unused water) *Costa de Cima*	***Lameiros em cima açude****(3D)* *Silva* ***Corredias*** *Costa de Baixo*

NOTES:

Hora da Costa

(3C) Flow division - The water flow is divided into 4 equal parts, *regos*, that are being allocated to (groups of) persons in the proportion 1:1:2. In the case of groups a fourth level can be distinguished.

(4C) Flow division - The water is divided into two equal parts

(4B) Plot-based - Rotation over 6 specific plots with every person irrigating until (s)he has enough. This could imply that the last plots to be irrigated will have to wait until the next turn. It is possible that the order of the rotation changes each time or each year.

Hora da Costa de Cima

(3D) Primarily the water is irrigating meadows upstream of the weir. Note that irrigation takes place directly from the stream without passing the reservoirs. Only water in excess that is left or unused, the so-called *corredias*, return to the stream, flow into or pass by the reservoirs and will be used downstream of the reservoirs.

(4A) Time shares - The *hora da Costa de Cima* (8 hours) is divided into two equal periods of 4 hours in which the water of the stream is allocated to different users.

(5) division of the 4 hours between JdB and the Herdeiros Albina is unknown. The Herdeiras Albina are a family which still have not divided their inherited rights.

- *Corredias* go to *Costa de Cima*, which is downstream of the *poças*. But is not clear if *Costa de Cima* refers to persons or a specific area, nor how the *corredias* are exactly allocated.

Hora da Costa de Baixo

- It is not clear if *Silva* refers to a person(s) or an area.

- *Corredias* go to *Costa de Baixo* which is downstream of the *poças*. But is not clear if *Costa de Baixo* refers to persons or a specific area, nor how the *corredias* are exactly allocated.

DIA DO PACO			
HORA DO VALDEMAR	*HORA DO TIMOTE E HERDEIROS*	*HORA DO MORGADO*	*HORA DO PEREIRA*
VDP	*Vez sim* (odd turn) ***6 regos*** *(3C)* *1. FsdaCr* *1. OSG* *1. MM* *1. MBS* *1. AnaS* *1.* OSG: 4 leiras* (short furrows/small plots) *resto* (remainder)*: (4B)* *DP & AS* ------------------------ *vez não* (even turn) ***7 regos*** *(3C)* *1. FsdaCr* *1. OSG* *1. MM* *1. MBS* *1. AnaS* *1. DP & AS* *1.* OSG: 4 leiras* *resto: (4B)* *FsdaCr* *OSG* *MM* *MBS* *AnaS*	*Ano sim* (odd year) ***6 regos*** *(3C)* *3. FPL* *1. OSG* *1. FP* *1. AGO* ------------------------ *ano não* (even year) ***4 regos*** *(3C)* *2. FPL* *1. OSG* *1. FP*	*1 vez sim* (one turn in three) ***baixo*** *(3C)* *½. JP* *½. AvPL* ------------------------ *2 vezes não* (two turns in three) *lameiros em cima de açude (3D)* *DPE* *Corredias* *JP*

NOTES:

Hora do Valdemar

- The whole time share is only for one right holder.

Hora do Timote e Herdeiros

(3C) Flow division - The water flow is at an odd turn (*vez sim*) divided in 6 or at an even turn (*vez não*) 7 equal parts.

(4B) Plot-based allocation

- * OSG can use his *rego* only to irrigate 4 specific furrows or small plots. After that the remaining water enters in a plot-based allocation between 2 right holders (odd turns) or 6 right holders (even turns). What will be the irrigation sequence in and between turns in the plot-based groups is not known.

Hora do Pereira

(3C) Flow division - the water flow is divided in 2 equal parts

(3D) Primarily the water is irrigating meadows upstream of the weir. *Corredias* return to the stream, flows into or passes by the reservoirs and will be used downstream of the reservoirs.

DIA DE JOANA AFONSO			
HORA DO FELISBERTO	*HORA DO BARACO E HERDEIROS*	*HORA DO ?*	*HORA DA CASA DO SANCHES*
FP	*Ano sim* (odd year) *ADC* ------------------------- *ano não* (even year) ***4 regos*** *(3C)* *3. ADC* *1. (4B)* VDP *DaPL* *MGV*	***Lameiros em cima de açude*** *(3D)* *Herdeiros do Torneiros* ***Corredias*** *FPL*	***Roda* (‘wheel’)** *(3B)* *casa do Sanches* *(23 pessoas)* *ano sim* (odd year): *roda começa em cima* ------------------------- *ano não* (even year): *roda começa em baixo*

NOTES:

Hora do Baraco e Herdeiros
(3C) Flow division
(4B) Plot-based allocation

Hora do ?
(3D) Primarily the water is irrigating meadows upstream of the weir. These meadows are the property of farmers (the *herdeiros do Torneiros*) in the neighbouring village of Covas. C*orredias* will be used downstream of the reservoirs.

Hora da casa do Sanches
(3B) Plot-based allocation. The water rotates over 23 plots. The group of right holders are called the *casa do Sanches* (lit. the Sanches household). When certain plots are not irrigated in this day-period then irrigation will continue at the *Dia do Fundo de Vila*. Only after all 23 plots have been irrigated a new irrigation turn will start. In odd years the sequence of plot irrigation (a *roda começa em cima*: lit. ‘the wheel starts from above’) is the other way around than in even years (a *roda começa em baixo*: lit. ‘the wheel starts from below’)

DIA DE TRAVESSA		
HORA DA COSTA	*HORA DOS LAMEIROS DO ILVA*	*HORA DO FELICIO E HERDEIROS*
MAC	***Lameiro em cima de acude*** *(3D)* *AV* ***Corredias*** *Herdeiros de Valdasnela (4B)*	***4 regos*** *(3C)* *2. FG* *1. VDP & JGC* *1. (4B)* *roda 5 pessoas:* *AvPL* *FPL* *JPM* *MMG* *VDP*

NOTES:

Hora dos Lameiros do Silva
(3D) Primarily the water is irrigating meadows upstream of the weir. C*orredias* will be used downstream of the reservoirs.
(4B) Plot-based allocation between de *herdeiros* (heirs) *de Valdasnela*

Hora do Felício e Herdeiros
(3C) Flow division
(4B) Plot-based allocation between 5 plots

DIA DO LABANCO		
HORA DO LABANCO	*HORA DO BARROCA ARIAL*	*HORA DO MEIRES*
8 regos *(3C)* *4. FPL* *2. AJP* *1/2. ASM* *3/2. DPF*	***4 regos*** *(3C)* *2. AB* *2. ano sim* (odd years) *JBE* ----------------------------- *ano não* (even years) *1. OSG* *1. FP*	***Primeiro* (first) *:*** *(3B)* *vez sim* (odd turns) *OSG* -------------------------- *vez não* (even turns) *Api & MG* ***depois* (after) *:*** *3 regos: (4C)* *1. (5B)* *rego do Loureiros (roda 8 pessoas)* *1. (5B)* *rego da Ginjeira* (*roda 10 pessoas*) *1. (5B)* *ano sim* (odd years) *rego do Meires (roda 10 pessoas)* --------------------------------- *ano não* (even years) *rego do Muro da Laja (roda 4 pessoas)*

NOTES:

Hora de Labanco
(3C) Flow division

Hora do Barroca Arial
(3C) Flow division

Hora do Meires
(3B) Plot-based allocation. First a plot of OSG (odd turns) or a plot of APi & MG (even turns) will be irrigated. After irrigation of one of these plots the flow will be divided into 3 equal parts (4C).
(5B) Plot-based allocation

DIA DE VIACOVA		
HORA DE FPL	*HORA DE RIGUENGO*	*HORA DE PEREIRA E HERDEIROS*
FPL	*2 regos (3C)* *1. DAR* *1.(4C)* *vez sim* (odd turn) *1/3. OSG* *1/3. MMm* *1/3. JD* ---------------------------- *vez não* (even turn) *½. OSG* *½. MMm*	*2 regos (3C)* *1 .Casa de Pereira* *(roda 16 pessoas) (4B)* *ano sim* (odd year) *roda começa em cima* *Continuação do Dia do Fundo da Vila* (Continuation of Irrigation of the *Dia do Fundo da Vila*) ---------------------------- *ano não* (even year) *roda começa em baixo* *Continua no Dia do Fundo da Vila* (Irrigation will Continue on the *Dia do Fundo da Vila*) *1. meia hora do moucim (4C)* *1/2 e pouco – AgFL* *resto: (5)* *- AvPL* *- AP & DPF*

NOTES:

Hora de Riguengo

(3C) Flow division into two equal parts. One part is one more time divided in 3 equal parts at uneven turns and in 2 equal parts at even turns (4B).

Hora de Pereira e Herdeiros

(3C) Flow division in two equal parts.

(4B) Plot-based allocation. The water rotates over 16 plots. The group of right holders are called the *casa de Pereira* (lit. the Pereira household). When certain plots are not irrigated in this day period then in even years, irrigation will continue at the *Dia do Fundo da Vila*. Only after all 16 plots have been irrigated a new irrigation turn will start. In odd years it's the other way around, that is to say irrigation of the 16 plots will start at the *Dia do Fundo da Vila* and continue on the *Dia de Viacova*. At the same time this sequence is combined with still another sequence. In odd years the sequence of plot irrigation (*roda começa em cima*: lit. The wheel starts from above) is the reverse of even years (*roda começa em baixo*: lit. The wheel starts from below)

(4C) flow division in 2 unequal parts: 1/2 and a little more (*1/2 e pouco*) and what remains (*resto*).

(5) It's not clear how the water is allocated between AvPL and AP&DPF.

DIA DO FUNDO DE VILA		
HORA DO RIGUENGO	*HORA DO FELICIO*	*HORA DO PEREIRA, CAXIMOUROS E CASA DO SANCHES*
DAR	*FG*	***3 regos*** *(3C)* *1. casa do Pereira (4B)* *(roda 16 pessoas)* *ano sim* (odd year) *roda começa em cima* *Continua no Dia de Viacova* (Irrigation will Continue on the Dia de Viacova) ----------------------------- *ano não* (even year) *roda começa em baixo* *Continuação do Dia de Viacova* (Continuation of the Dia de Viacova) *1. caximouros (4B)* *(roda 11 pessoas)* *1. casa do Sanches (4B)* *(roda 23 pessoas)* *ano sim (odd year)* *roda começa em cima* *Continua no Dia de Joana Afonso* (Irrigation will Continue on the Dia de Joana Afonso) ------------------------------------- *ano não* (even year) *roda começa em baixo* *Continuação do Dia de Joana Afonso* (Continuation of the 'Dia de Joana Afonso)

NOTES:

Hora do Pereira, Caximouros e Casa de Sanches

(3C) Flow division in 3 equal parts

(4B) Plot-based allocation. In even years the plots of the *casa de Sanches* which have not been irrigated during the *Dia de Joana Afonso* will now have their turn. In odd years it is the other way around. Similar rules apply for the *casa de Pereira*.

DIA DOS MUITOS			
HORA DO REI	*HORA DO CORTINHO*	*HORA DO TORGÃO*	*HORA DO ANTONIO ARCOS*
Ano sim (odd year) ***4 regos*** *(3C)* *1. OSG* *3. FPL* ------------------------ *ano não* (even year) ***12 regos*** *(3C)* *4. FPL* *6. FP* *1. MS* *1. (4B)* *OSG & herdei-* *Ros da casa do* *Sanches*	***4 regos*** *(3C)* *2. Veiga:* *1. (?)* *EPL* *ADSA* *1. (?)* *OSG* *AvPL* *BdaCR* *2. vez sim* (odd turn)*:* *terras de cima* *1.(?)* AP *JMG* *1.(?)* *AnaS* *OSG* *MBS* -------------------------- *vez não* (even turn)*:* *cortinhas* *1. FPL* *1. DoPL*	***8 regos*** *(3C)* *2. MS* *2. AgL* *1. DPF* *1. MM* *1. AS* *1.(?)* *AbPL* *MRL*	 *AA*

NOTES:

Hora do Rei
(3C) Flow division
(4B) Plot-based allocation

Hora de Cortinho
(3C) flow division
- the *veiga* is a very intensively cultivated area with the best manured plots. *Cortinha* is the name of a plot in the *veiga*. *Terras de cima* are fields that are situated more upwards.

(?) It is not known on what basis the water is divided within this groups (plot, further flow division)

Hora do Torgão
(?) It is not known on what basis the water is divided between these two water users.

DIA DA ACRESCENTADA			
HORA DO TIUFE	*HORA DA VEIGA*	*HORA DO PORTELA*	*HORA DO COTO*
Em cima de poças (upstream of the reservoirs) *primeiro* (first) *DAR* *Depois* (after) *DPE*	***6 regos*** *(3C)* *3. AgL* *2. MS* *1. DPL*	***4 regos*** *(3C)* *2. APo, da 1/2 rego a JGV* *1. FPL, da 1/4 rego a MS* *1. DoPL, da 1/4 rego a MS*	***4 regos*** *(3C)* *1. FP* *1. AS* *1. AvPL* *1.* *Vez sim* (odd turn) *- FPL* ------------------------ *vez não* (even turn) *- OSG (4 leiras)* *- FPL*

NOTES:

Hora do Tiufe

- Plots will be irrigated upstream of the reservoirs. First DAR's plots will be irrigated, afterwards plots of DPE.

Hora da Veiga

(3C) flow division

Hora do Portela

(3C) flow division

- The three persons APo, FPL and DoPL all have to give a quarter part of their water to someone else. In the case of APo this amounts to half a *rego* that goes to JGV. FPL and DoPL each give quarter of a *rego*, so MS gets half a *rego* as well.

Hora do Coto

(3C) flow division

The odd turn FPL can use the whole *rego*, the even turn OSG has a right to irrigate 4 specific plots (*leiras*), after that FPL will receive the water.

Notes on the water allocation schedule

From this complex allocation schedule some main points can be derived:

- The allocation schedule contains explicit rules to convert allocation in distribution. They aim to create *average equal conditions* to convert water rights in water flows, for instance to even out or minimise the effects of flow variations between irrigation turns and interannual variations in flows available for irrigation. Examples of this principle are the different sequence of days in even and odd years (1st level), the variation of the place of the *poçadas* in the day (2nd level), the clock-wise and anti clock-wise rotation of plot-based irrigation (*roda começa de cima/de baixo*). Related are the rules which determine different water allocation at odd/even turns (*vez sim*, *vez não*) and in odd/even years (*ano sim, ano não*).

The effects of the varying outflow from the reservoir are balanced out over the different users of a poçada by plot-based allocation, flow division and the compensatory mechanisms mentioned before. It is not accidental that the division of the reservoir outflow is not realised by means of time shares because that is difficult to realise with the varying reservoir outflow. This is only possible in specific designed reservoirs, as I will show in Chapter 7.3.

- The actual water allocation clearly reflects the historical development of water rights, heritance processes and transactions of land and water rights. Examples are the names of days and *poçadas* which mostly bear the names of historical households (and heirs), e.g. *Casa do Sanches*. Remarkable is also that the plot-based water allocation occurs frequently. That is clearly a consequence of heritance processes in which land is divided but water rights are not. This is different from the division of flows and irrigation times, which also is present. Another interesting phenomenon are the explicit and special rights assigned to the owners of *lameiros* (meadows upstream of the weir, meadows between weir and reservoir on Sundays, parallel to the schedule). This reflected clearly the weight and the importance of the rich farmers (*lavradores abastados*, see Chapter 5) in the past. An intriguing phenomenon is also the *corredias*, excess water that present losses occurring in *lameiro* irrigation. It can be hypothesised that the schedule may have had only 7 days in the past and the *Dia dos Muitos* (lit. 'the day of the many') and the *Dia da Acrescentada* (lit. 'the additional day').was added only later. Plausible indications for that hypothesis could be the typical names/terms in the schedule and the place of these days in the schedule: They come last in each irrigation cycle (see Table 3.1).

- The whole schedule gives the impression of a tendency towards involution as is reflected in 'an increasing tenacity of the basic pattern, the gothic elaboration of technical and organisational detail, technical hairsplitting and unending virtuosity'(Geertz 1963:82), e.g. in the schedule at the *Dia do Acrescentada*, *Hora do Portela*, the farmers FPL and DoPL receive ¼ of the flow each, ¼ of each accrues to the farmer MS.

Another striking example of these characteristic is the water allocation in the *Hora do Meires* of the *Dia do Labanco*: The distribution group *rego do Meires* (10 persons) receive 1/3 of the streamflow in an odd year but only after a plot of OSG (odd turns) or a plot of APi & MG (even turns) has been irrigated. For a person of this plot-based distribution group, irrigation of his plot is still more complicated because the moment of irrigation is uncertain: it depends on available flows and the other users in the group.

Still some flexibility is possible. In case a water user has the exclusive right to a whole day period (*hora* or *poçada*), he has the possibility to use the water on the plots of his choice. Although more difficult in practice, it is possible that within a flow division group, people can arrange to use their water on preferential plots. It is also possible to exchange irrigation turns under this allocation principle.

- The dispersion of land in many plots leads also to a dispersion of irrigation times and turns. This can be illustrated by the irrigation events of OSG household in one irrigation interval (see Table 3.2)

Table 3.2 OSG's irrigation activities/events (according to the allocation schedule)

	Uneven Years		Even Years	
Days irrig. Interval	Uneven turn	Even turn	Uneven turn	Even turn
Dia da Costa	a) 1 plot (*roda*)	a) 1 plot (*roda*)	a)1 plot (*roda*)	a) 1 plot (*roda*)
Dia do Paco	b) 1/6 * 1 *poçada* +4 *leiras* (*roda*) c) 1/6*1 *poçada*	b) 1/7*1 *poçada* + 4 furrows (*roda*) c) 1/6 *1 *poçada*	b) 1/6*1 *poçada* + 4 furrows (*roda*) c) 1/4*1 *poçada*	b) 1/7 *1 *poçada* + 4 furrows (*roda*) c) 1/4 *1 *poçada*
Dia de J. Afonso	-	-	-	-
Dia de Travessa	-	-	-	-
Dia da Labanco	d) 1 plot	-	d) 1 plot e) 1/4*1 *poçada*	 d) 1/4 * 1 *poçada*
Dia de Viacova	e) 1/6 * 1 *poçada*	d) ¼ * 1 *poçada*	f) 1/6 * 1 *poçada*	e) 1/4 * 1 *poçada*
Dia do F. de Vila	-	-	-	-
Dia dos Muitos	f) 1/4 * 1 *poçada* g) 1 plot (*roda*) h) 1 plot (*roda*)	e) ¼ * 1 *poçada* f) 1 plot (*roda*)	g) 1 plot (*roda*) h) 1 plot (*roda*) i) 1 plot (*roda*)	f) 1 plot (*roda*) g) 1 plot (*roda*)
Dia da Acrescentada	-	g) 4 *leiras* (*roda*)	-	h) 4 furrows (*roda*)

Notes:
- *roda*: plot-based irrigation sequence: in this sequence it is not sure that the plot will receive water each turn. If the plot has not received the water, it will probably receive it during the next or even the 3rd turn (see Chapter 2).
- *leira*: short furrow or (very) small basin

Confusion at the start of the summer irrigation

Every year at the first two weeks of the summer irrigation confusion may occur. The water allocation and distribution schedule is very complex with sequences of days, periods and water users differing every turn or every year.

In 1992, the president of the parish council (*Junta de Freguesia*) decided that even without the canals being cleaned (normally this happens around June 24, the feast of S.João), the summer irrigation schedule should start on Monday, June 22. In 1992, S.João was on a Wednesday but the allocation schedule (*rol*) always has to start at a Monday. A lot of people in the village did not agree with this decision for two reasons. First, in winter everyone in the village has the right of access to water on the basis of the *a vez* rule but some households do not have water rights in summer. This meant that with the start of the summer schedule these households would have no access to irrigation water until the end of the summer period. Second, people argued that it had rained a lot before and not everybody needed water. Especially plots with potatoes did not have to be irrigated yet. Meadows, however, always require water. It might have been better, they said, to start summer irrigation a week later. In that case people with summer rights still would have the possibility to use the water on meadows and other plots not included in the allocation schedule.

It appeared also that not everybody knew summer irrigation already had started. And even users who knew, often did not know at what time exactly they had to irrigate. One of the reasons for this could be that the need for irrigation water is still not pressing because even when the upper soil layer seems dry, the plant roots can take moisture from lower soil layers which are still wet (at field capacity). However it may be, the first rotation cycle is always difficult. After the first irrigation interval everybody knows what to expect.

During and after the intervention

In Romainho the layout of the system as it was, apparently satisfied the farmers and they wanted it to stay like that. In the intervention, the location and dimensions of the original canals and reservoirs have been maintained. This enabled them to continue the water distribution according to the actual allocation system. Technicians of the *Zona Agraria*, the zonal office of the regional directorate of agriculture reported that no changes have taken place in the system, neither in the water allocation nor in agronomic practices. The technicians stated that as a consequence of 'the MRT intervention an increase of the meadow area should have been registered, a decrease of the cultivated potato area and more intensive cultivation practices using more fertilisers' (Cordeiro 1992c).

However, not all water users seemed satisfied with the existing situation. They asked the engineers who were charged with the design and implementation of the improvement for advice, formalised in a request. Various farmers in Romainho wanted more changes in the irrigation system than just physical improvements. They wanted to change the water right system on this occasion, mainly because the existing water allocation system was very complex. Moreover irrigation turns are very scattered, leading to time-consuming practices (see Table 3.2). Some people thought the rights inequitably distributed.

The exact content of the request for a new water rights system is not fully understood. Indeed, two requests have been formulated and it is not clear if they are contradicting each other or essentially propose the same.

The first request was signed by 40 persons, 18 of which signed in the name of others, probably emigrants. This proposal is very short and requests an allocation of water on the basis of time shares. According to the villagers, the idea has been something like allocating the water for a whole day to one secondary canal. Then within this part of the system people could arrange a division for themselves.

The second request is signed by 4 members of the irrigators' council (JAR) which legally need to be established in order to be eligible for MRT intervention. This proposal is more elaborate but problematic. The main proposed change was to allocate the water on basis of the irrigation of a defined area per unit time in summer and winter, respectively 1800 m^2 per hour in the summer period (24/6 – 29/9) and 1200 m^2 per hour in the winter period (29/9 – 24/6). From the proposal it is not clear which time concept is referred to: does it refer to the time of inflow to the reservoirs (24 hours/day) or to actual field irrigation time which is nearly equal to the daily outflow period of the reservoir corresponding to approximately 4.5-5 hours/day[14]). Nor is it indicated how the water is to be distributed according to this new allocation criterion[15] which is essentially a time-share allocation. It is highly probable that this proposal was suggested by MRT technicians because the criterium of a uniform water allowance per unit area or a uniform irrigation intensity I never encountered explicitly in the numerous Trás-os-Montes systems[16] I visited. On the other hand it is proposed to maintain the actual water rights and distribution practices for the meadows upstream of the weir (*lameiros em cima*). The *corredias* would be distributed in an irrigation intensity of 480 m2 per hour. It was further proposed to appoint an official (*zelador de regadio*) in order to operate the reservoir and to 'join the waters' during the summer period.

A change in the system of water rights as proposed here would imply changes in the infrastructure, distribution rules and operational mechanisms as well.

However, not all users of the system agreed with the request, so it was not elaborated further. Farmers with extensive water rights in the system, e.g. the exclusive right to use the water associated with one or more day periods, which give them more flexibility in deciding when and where to irrigate, did not agree with the change. So everything remained the same. Still, principally young farmers in the village have difficulties with the system of water rights. They think it is too complicated and do not understand why no other system is practised.

Conclusions

The irrigation system of Romainho is a clear example of a skill-oriented technology in which a primitive physical infrastructure without distribution structures is compensated for by an elaborated system of water rights and a variety of (compensating) rules to convert water allocation into water distribution. In time, the functioning of the system has become increasingly complex and now tends to involution. Maybe the improvement intervention was a missed opportunity to reorganise the system.

3.2 From allocation to distribution: The functioning of the communal irrigation system in Vila Cova

In this case study[17] I will highlight the complex transformation of water allocation in water distribution. This transformation is not automatic or deterministic, it is the outcome of a historical process in which the diverse interests of local water users are brought in line between each other and the characteristics of the natural environment. The water users of Vila Cova, one of the Trás-os-Montes villages, have crafted a set of rules to translate abstract water rights into actual water flows to the irrigated plots during determined periods of time, in other words to distribute the water in accordance with the allocation. I will focus on the internal coherence and the logic underlying these rules. The conversion of rights into distribution is often a complex process and might transform a fair allocation into an unfair distribution. The rules that the irrigators have developed in Vila Cova provide the water users with fairly equal opportunities to obtain the water to which they are entitled[18].

I will start by presenting the history and details of irrigated agriculture and contemporary water allocation in Vila Cova.

Physical and socio-economic environment

Vila Cova is a mountain community of farming households in Trás-os-Montes. The village lies 17 km from Vila Real, the main city of the region (see Figure 2.2, village #03) on the edge of the mountain chain of Alvão, at 750 m above sea level. The climate is harsh, with cold, wet winters and hot, dry summers. Average yearly rainfall amounts to 1,870 mm, 85 per cent of which falls between October and March. Crop growth is constrained by low temperatures in spring, risk of frosts in the crop-growing season and a moisture deficit in summer.

Vila Cova is inhabited by 250 persons, who belong to 100 households. At least 40 of the 150 houses in Vila Cova belong to emigrants who only occupy them in August, during their summer holidays. The social infrastructure includes a chapel, a church, a primary school (seven pupils in 1992), and three small shops/cafes. Electricity and tap water are present. Public matters are handled by the Parish Council (*Junta de Freguesia*). Social life in Vila Cova is informal. Family ties are the most important social relations. Exchanges of resources, particularly of labour, between neighbours are also crucial.

Vila Cova prospered between the 1940s and the 1960s, when iron ore mining was an important source of income. Its population nearly doubled, houses were built and rented out and all agricultural production was consumed and sold locally. The closure of the mines and the fall of prices for agricultural products brought about the village economic decline. Since 1960, many farmers have migrated to Portuguese cities and neighbouring countries. The population has diminished to less than half, and today nearly every family has a relative working abroad. The result is an ageing resident population, with pensioners over 65 years representing nearly 40 per cent of the inhabitants. Only a quarter of the households[19] are engaged in full-time farming. The others combine farming with off-farm activities. Nevertheless, agricultural production remains an essential part of the consumption and income of most households.

Agriculture

The households in Vila Cova own small landholdings, which comprise many small, scattered plots. Currently, agriculture is constrained by a lack of labour. Production processes continue to be labour-intensive although many household members have left the village. Therefore, elderly people and children contribute to daily activities (herding etc.) and household members engaged in off-farm work during the week usually help on Saturdays[20] and during holidays. Mechanisation is increasing gradually. In peak periods, additional labour is mobilised through exchanges with neighbours and family members. Other resources are also obtained through such exchanges.

Farming in Vila Cova has hardly specialised. All families cultivate potatoes, maize[21] and vegetables, mainly for home consumption. Nearly all cultivated land (arable and meadows) is irrigated which is rather exceptional in the Trás-os-Montes setting[22]. Some farmers gain additional income by raising cattle for milk and/or meat, but the average herd is only two animals. Animal feeding is based on meadows for green fodder, grazing and hay. Only one farmer owns a flock of sheep which he usually grazes on the communal lands. These also supply firewood and material for cattle bedding.

Irrigated agriculture and water sources

All water sources are exploited for agricultural purposes, even those with flows of less than 1 l/s. The most important water source is the river that passes through the village, the Ribeiro de Vila Cova. Although its flow decreases considerably when summer advances, it is the main source for summer irrigation water. Other sources are springs, galleries, shallow and deep wells. These are owned and used individually or by small groups. The river water irrigates the main part of the cultivated land (named *veiga*) of the village by means of a collective irrigation system (*rego do povo*). Summer flows in the system range from about 10 to 25 l/s which are perfectly manageable with the practised surface irrigation methods. An important feature of the system is a continuous flow during 24 hours per day which implies night irrigation and the absence of storage facilities at system level[23].

Irrigated agriculture is divided into winter and summer irrigation. During these periods the area irrigated, allocation arrangements and distribution rules differ. In winter these arrangements are rather loose, since available water greatly exceeds demand. In summer, arrangements are strict, since scarcity of water and increased crop water requirements easily lead to greater competition for water.

Winter irrigation: from October until June

In the winter period most river water is used on permanent natural meadows (*lameiros*) on the slopes of the river valley[24]. The meadows produce hay and are grazed after the hay harvest. Most meadows are situated upstream of the village and of the main intake that supplies the irrigated *veiga* (see below). Brushwood dams convey the water into earthen contour canals, which spill over to the adjacent meadows. These irrigation facilities are owned and maintained by small groups or by individual water users.

During the winter, access to water is free: all villagers may use the water where and whenever they want. Agreements between the water users are made only when the flow diminishes. Nevertheless, the basic rule of ‘first come, first served’ is applied: as long as a water user is irrigating his field, he must be respected; consequently, the water may not be diverted by others[25].

Summer irrigation: from the end of June until the end of September.

During the summer water is mainly applied to food crops cultivated primarily for household needs. However more and more water is used for permanent meadows and the cultivation of cattle feed (meadows for green pasture, green maize etc.). The demand for water increases during the summer, since crop water requirements increase and the rainfall diminishes.

The principal summer irrigation area is the *veiga*, a flat area of deep, heavily manured, good quality soils located near the village. Its 32 ha are divided into about 260 plots with an average size of 0.12 ha. In the *veiga* a very intensive land use is practiced consisting in an annual succession of a summer food crop, principally potatoes and maize (April/May-September) and sown pasture in the winter (October-April)[26]. The irrigation water for the *veiga* area is obtained from the communal irrigation system of Vila Cova.

The communal irrigation system

In the system that serves the *veiga*, 82 of the 100 Vila Cova households have access to the water. The system is called *o rego do povo* that means literally 'the People's Irrigation Canal'. Figure 3.4 shows the communal irrigation system and the present and former landholdings (*casais*) that it includes. The system comprises a permanent diversion structure in the Vila Cova river, a conveyance canal of 50 m in length, which bifurcates into two primary canals dug out in rock and soil[27] that split into various branches downstream, totalling about 3,500 m. The system mainly serves the *veiga*. Water users derive the irrigation water directly from these canals and convey it through a network of field channels to their fields. The operation of the communal system is subject to detailed rights, rules and regulations that are the outcome of historical processes. These will be discussed below.

Water allocation in the communal irrigation system

The origin of the actual water allocation dates back to the time that the *veiga* was the property of nine *casais* (plural of *casal*), homesteads of relatively rich households cultivating determined areas of land. In a collective effort the *casais* created the infrastructure to irrigate their landholdings. It is no longer remembered when and how this was done. From the actual allocation it may be hypothesised that from the outset every *casal* obtained a time share of water more or less proportional to its area and that a mono-flux rotation among the *casais* was established. This rotation lasted 11 days: eight of the nine *casais* were allowed to use the whole water flow for 24 hours, the ninth *casal* was entitled to use it for three days. The days of the rotation were named after the respective *casais*. The distribution within the *casal* landholding was not further prescribed; the water could be used according to the desire of the family holding the water rights.

Current allocation is based on this historical foundation, but consists of two levels. The first level corresponds to the original rotation among *casais*. The days of the rotation still bear the names of the historical *casais* or the cultivated areas that they owned. The difference is that the three-day period associated with the ninth *casal* has been divided into separate days. The second level refers to the allocation within every *casal* day. The 24 hours have been fragmented into smaller time shares belonging to different water users.

This fragmentation largely coincided with the fragmentation of the landholdings that occurred as a consequence of inheritance, marriage and buying and selling. With every division of land the water right related to the land was also divided into smaller portions. Water rights have also been exchanged, bought and sold independently, and this has blurred the formerly clear-cut water allocation. Still there exist a certain proportionality between the size of time shares and irrigated areas (Carvalho 1994)

The result of the fragmentation is that most farmers have plots and attached water rights in several historical *casal* landholdings. Although these rights may have been fragmented, each right remains defined in terms of the time that the whole water flow may be used and in terms of its place in the *casal* allocation sequence. These time shares vary from a few minutes to several hours. Accumulated access to water varies greatly among the water users: some users have access to several minutes only, whereas a few others total up to over ten hours of water right.

All time shares and their order are written down in an allocation schedule. The most recent water allocation schedule dates back to 1968 and is in the possession of the president of the Village Council and a small number of farmers. Table 3.3 shows a transcript of the water schedule of casal Portêlo.

The water schedule is far from accurate. It gives names of right holders who are no longer active water users, and time shares do not always correspond with the present allocation of irrigation water. During the irrigation season of 1992, however, these deficiencies gave rise to few doubts or comments about the water rights.

Figure 3.4 *Rego do povo* and *veiga* area (communal irrigation system of Vila Cova)

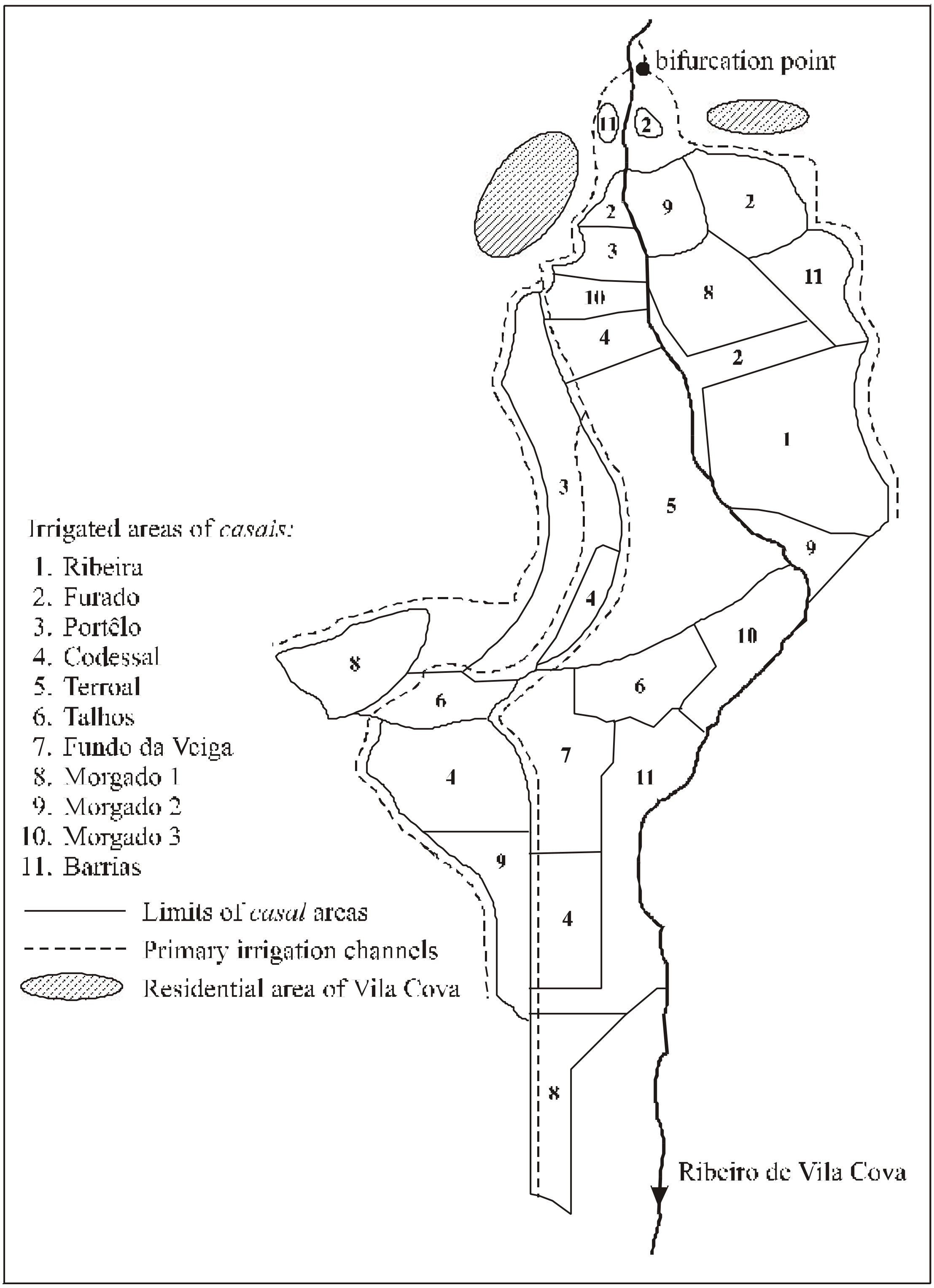


Table 3.3 The water allocation schedule of *casal* Portêlo (transcript, in Stam 1993)

The third *casal* Portêlo begins in '*Ovelheira*', goes on to '*Portêlo*' and ends in '*Tapado*'.

Place	*Name of user*	*Hour*	*Minutes*
Ovelheira	Cândida Duro		42
	Maria Emília da Fonte		42
	Delfina Duro		7
Portêlo	José Manuel Duro	1	8
	América de Barros		12
	Amélia Duro		8
	José Pereira	1	59
	Delfina Duro		53
	Manuel Joaquim Carvalho Duro		25
	Joaquim Alves		18
	António Farroco		18
	Filomena Farroco		50
	Januário da Fonte		30
	Ana Pereira		24
	Conceição Pereira		23
	António Martins Ondas		23
	Ermelinda Duro		5
	Manuel Conçalves		5
	Teresa Lourenço		35
	Joaquim Carvalho		30
	Manuel Joaquim Duro		15
	Joaquim Gravelos		7
	António Martins Ondas		57
	Januário da Fonte		30
	António Pereira Gouvinhas		13
Tapado	Manuel Augusto Moreira	2	10
	Francisco Freixieira		5
	Joaquim Carvalho		6
	Joaquim Carvalho		40
	Belarmino Ramalho		30
	Joaquim Alves		18
	José Manuel Duro		34
	Joaquim Gravelos		15
	João Pereira Vasconcelos		31
	Florinda Pires	1	
	América Calado		43
	Manuel Augusto Moreira		51
TOTAL		22	22

This *Casal* has water for 22 hours and 22 minutes and includes a travel time of 1 hour and 38 minutes.

Water distribution: rules and mechanisms to transform rights into flows

The allocation of time shares forms the basis of the distribution of water among the users. However, distribution in practice is not a linear translation of the allocation shares. The management of water flows involves a set of issues that are not included in the allocation schedule. It raises questions such as what to do with water losses in canals, how to cope with the travel time of water, what sequence of users to follow, and how to distribute night turns. These issues need to be addressed to be able to convert the allocation schedule in practical discharges.

Over time, the water users of Vila Cova have elaborated a number of rules and mechanisms to convert allocation in distribution. These arrangements govern the day-to-day operation of their system. They contain much detail and address a variety of questions.

Beginning and ending the summer irrigation period

The beginning and end of the summer period are important dates, since water distribution is strictly arranged only during this period. Officially, the summer period starts on 24 June, the feast of Saint John and ends at 29 September, the feast of Saint Michael. In the past this period was rigidly fixed. Outside this period river water was exclusively allocated to upstream *lameiros* and mills. One of those mills was located at the head end of the main canal. Because of the required drop in water levels for the functioning of the mill, water could not flow to the *veiga* area but flew directly back to the *ribeiro* (Carvalho 1994:54). Nowadays, this mill is not in use anymore and water can flow the whole year to the *veiga*. However, the summer period starts when water users feel that they have to wait too long under the ‘first come, first served’ rule. They start to pressure the Parish Council to apply the summer irrigation schedule.

This practice makes the date to start summer irrigation flexible. In 1992, for instance, it was decided to postpone summer irrigation until the 29 June, since water was still abundant due to abundant rain showers in the first three weeks of that month. Because of similar reasons summer irrigation in 1993 started exceptionally late (15th of July). The summer period may also start before the official date. When this happens, the meadows upstream of the intake of the communal system are nevertheless allowed to be irrigated until 24 June. The date of the last day of the official summer period is also flexible. When rains appear early in September, the summer distribution is abandoned before the end of the month.

Deciding which group starts the summer irrigation

Two Sundays before 24 June the priest announces in church that the next Sunday, after mass, it will be decided where that year's irrigation will start. For this purpose, the *casais* are divided into two fixed groups, named Veiga (seven *casais*) and Morgado (four *casais*). To decide which group may start off using the water, the president of the Village

Council invites someone to draw one of two straws representing the two groups. The group represented by the straw drawn may start to irrigate.

Deciding the sequence of the casais in the groups

Within the two groups agreements exist about the order of the *casais*. In the Morgado group this sequence is fixed: Morgado 1, 2 and 3 and then Barrias. In the Veiga group the sequence changes between odd and even years. In even years the sequence is roughly from the *casais* at the head end of the group to the *casais* at the tail end (from upstream to downstream, in the direction of the canal flow). In odd years the sequence is the reverse.

The sequences that are feasible may be found by combining the group that starts with the order of *casais* in the groups. This shows that four sequences are possible (Table 3.4).

Table 3.4 Possible sequences of *casal* irrigation days**.**

YEAR	EVEN Straw 1	EVEN Straw 2	ODD Straw 1	ODD Straw 2
START	***VEIGA***	***MORGADO ****	***VEIGA***	***MORGADO***
1	Ribeira	Morgado(1)	Fundo d.V.	Morgado(1)
2	Furado	Morgado(2)	Talhos	Morgado(2)
3	Portêlo	Morgado(3)	Terroal	Morgado(3)
4	Codessal	Barrias	Codessal	Barrias
5	Terroal	Ribeira	Portêlo	Fundo d.V.
6	Talhos	Furado	Furado	Talhos
7	Fundo d.V.	Portêlo	Ribeira	Terroal
8	Morgado(1)	Codessal	Morgado(1)	Codessal
9	Morgado(2)	Terroal	Morgado(2)	Portêlo
10	Morgado(3)	Talhos	Morgado(3)	Furado
11	Barrias	Fundo d.V.	Barrias	Ribeira

*In 1992 the straw of Morgado was drawn. Since it was an even year, sequence number two was followed.

The start of the casal day

Once it has been decided which group will start the summer irrigation, a clock is put in a window of the priest's house in the centre of the village. The time shown on this clock is 1.5 hours behind the official time. This difference stems from former days when a sun dial, attached to one of the houses, indicated the irrigation time. In 1957, this house and its sun clock were destroyed. Two months later a clock was purchased, which was set at the same time as indicated formerly by the sun dial. To date, the irrigation day of every *casal* has started around sunrise, at 4.00 h irrigation time (5.30 h official time). The next morning at the same hour the water flow is taken over by water users from the next *casal*.

The irrigation sequence within a casal

The sequence of water users within a *casal* changes with the irrigation turn of the *casal*. The idea is to avoid having the same water users always receiving their turn at night or at the end of the day. The irrigation turn of every *casal* is divided into three eight-hour parts and the water users of the casal are divided into three sub-groups. The order of these groups changes in every *casal* turn. For simplicity's sake we may call these groups A (upstream, water users 'a'-'g'), B (middle, users 'h'-'p') and C (downstream, users 'q'-'z'). One in every three turns each sub-group has to irrigate at night. Therefore three sequences between the sub-groups are established (see Table 3.5).

Table 3.5 Sequences of user's irrigation turns within a *casal*

Possible sequences/Water users	04-12h (day)	12-20h (day)	20-04h (night)
1. 'Upstream-downstream' >>>	A: a-g >	B: h-p >	C: q-z >
2. 'Downstream-upstream' <<<	C: z-q <	B: p-h <	A: g-a <
3. '*Salteado*' ><<	A: a-g >	C: z-q <	B: p-h <

*The time is indicated in local 'irrigation time'.

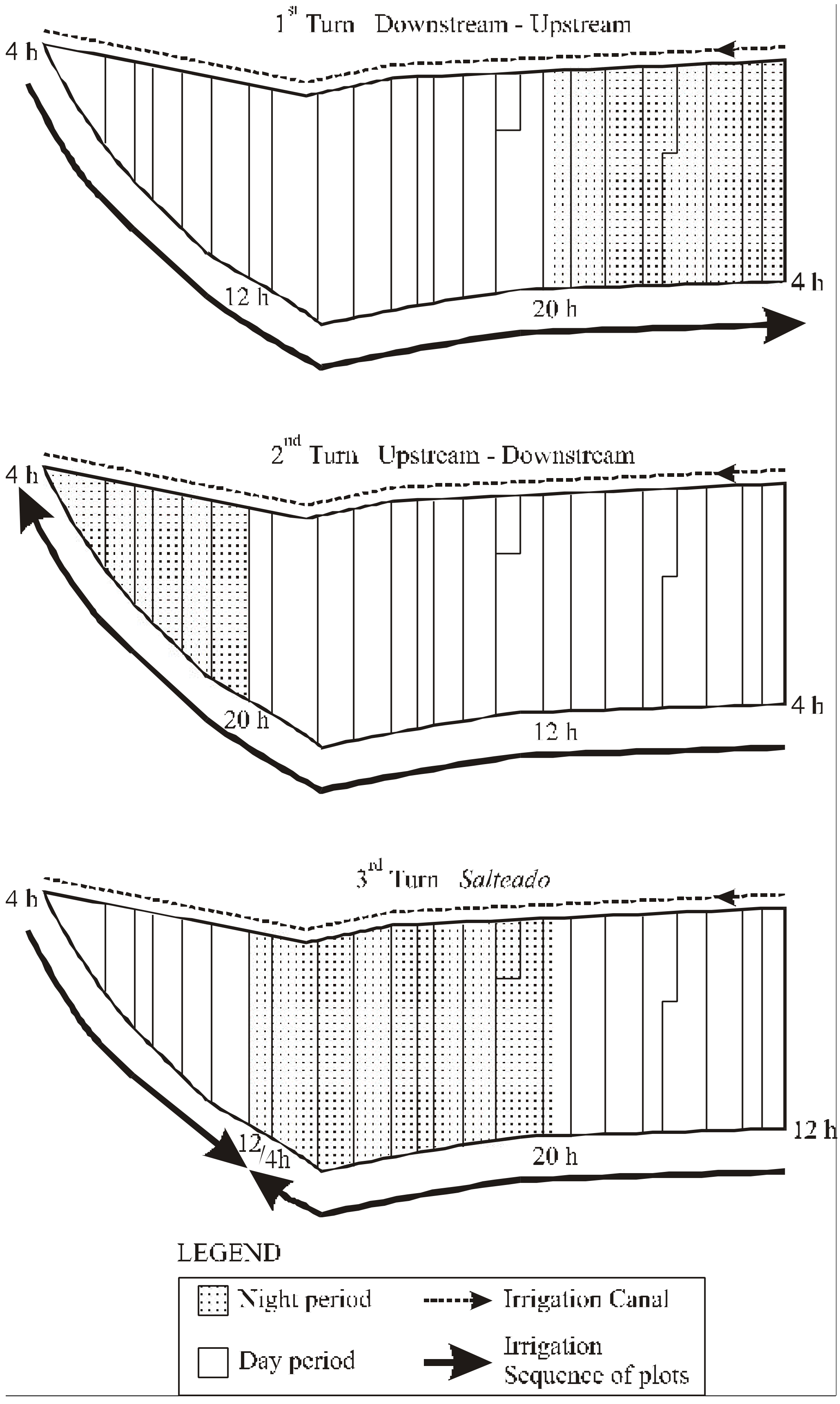
The first sequence follows the water from upstream to downstream (A-B-C; from user 'a'to user 'z'). The second sequence takes place in the opposite direction, from the last to the first water user (C-B-A; 'z'-'a'). The third sequence is called *salteado* (literally 'jumped'), in which the water makes a jump from the last person of sub-group A ('g') to the last person of sub-group C ('z'), so that sub-group B irrigates at night. This is nicely illustrated in Figure 3.5 adapted from Carvalho (1994). The *salteado* sequence causes higher canal losses (is technically less efficient) because of the 'jump'.

An additional rule states that the sequence chosen in the first turn of the year depends on the number of the year. In even years the first sequence is applied, in odd years the second.

Use of a water share

From the moment the water reaches a farmer's field, his time share is counted. During the time of his share, the water user is free to use the water in whatever way and on whatever plot he prefers. The moment that his share ends, his only obligation is to deliver the water at the point where the next user starts his turn. Because of this obligation, water of the smaller shares is often applied to the plot that it is officially destined for, since the time needed for the water to travel to other plots may exceed the duration of the water share. Water from larger shares may be transported to other plots, where irrigation is preferred. In Vila Cova it is common practice to divert the water flow of larger water shares to vegetable plots for a short time, in order to shorten the irrigation intervals for these drought-sensitive crops.

Figure 3.5 Sequences of irrigation turns within the *casal do Terroal*



Travel time of water

In Table 3.3 the sums of the time shares of the *casais* do not add up to 24 hours. The rest of the time is reserved for the travel of the water in the channels. It is composed of the time needed for the water to reach the *casal* area at the beginning of the irrigation day and the lead time between the plots within the irrigated area of a *casal*. During these periods water is not used for field irrigation. In *casais* in which there are groups of plots at different places and far from the source, travel times are higher, principally if these groups of plots are at the two opposite banks of the Ribeiro de Vila Cova (see Figure 3.4). In Vila Cova this travel time of water is literally called the ‘time of the irrigation canal’ (*tempo de rego*).

Vila Cova farmers have developed two rules to cope with this travel time. In some *casais* the travel time has been established as a fixed amount of time, which is not attributed to a specified water user. This amount of time (around one hour) should be enough to cover water travel time within the *casal* irrigation day. In other *casais* the travel time is proportionally deducted from the time shares of all water users. A total travel time of 60 minutes over 24 hours thus leads to a reduction of 2.5 minutes per hour of water share.

For at least three reasons these rules do not resolve all issues related to the transport losses of water. First, the travel time of water is not a fixed amount of time. It varies with water flow: when the water flow decreases in the late summer period, the travel time of water increases. Second, the notion does not take into account the infiltration losses in canals and the consequent reduction of flow in more remote sections. Third, the fragmentation of time shares into portions of only a few minutes makes it difficult to implement the reduction. A faulty estimation of the real travel time, a reduction of the irrigation shares that is too limited and the illegal prolongation of someone's time share (water theft) may deprive the last water users within a *casal* day of their full share.

However, the division of the *casais* into three sub-groups mitigates the shortcomings of the rules. Alternating the sequence of sub-groups in successive irrigation intervals means that the risk of not obtaining their full water share alternates between the users. This practice also equalises labour input to some degree, since the first water user of a *casal* generally has a harder job in conducting the water from the bifurcation point with the preceding casal to his plot than the following users.

Meanwhile travel times represent water volumes. One part represents canal conveyance losses, the other part denotes the water volumes resulting from the upstream cut-offs from the water flow. When the flow is cut off by a new user upstream then the water downstream from that point in the canal (called locally *cansos* or ‘waters in rest’) can still be used for irrigation. Normally the last user before water is cut off will take that water for his plot. Some problems of who has the right to use that water has occurred (Carvalho 1993:64) namely when a plot is divided for instance by inheritance.

‘Half water’ (Meia Água)

The summer irrigation turns last 11 days, except for the first turn, which is called ‘half water’ and lasts only six days. During this turn all *casais* are entitled to only half their water share, equalling 12 hours. To distribute night irrigation equitatively, each *casal* gets eight hours of water during the day and four hours at night. Only the last *casal* in the row has the full 24 hours to irrigate. Table 3.6 illustrates the distribution of ‘half water’ in 1992.

Table 3.6 ‘Half Water’ in 1992

IRRIGATIO N TIME	*First day*	*Second day*	*Third day*	*Fourth day*	*Fifth day*	*Sixth day*
4-12h (8 hrs)	Morgado (1)	Morgado (3)	Ribeira	Portêlo	Terroal	Fundo
12-0h (12 hrs)	Morgado (2)	Barrias	Furado	Codessal	Talhos	da
0-4h (4 hrs)	Morgado (1)	Morgado (3)	Ribeira	Portêlo	Terroal	Veiga

The rule on ‘half water’ dates from the time that demand was great for the first irrigation water directed to the *veiga*. The demand was pressing because of the rigid distinction between summer and winter irrigation. Until 24 June, all water was used on the meadows upstream of the arable land. When then after 24 June water was directed to the arable land in the *veiga*, soil moisture could have been already considerably depleted. Therefore, all water users wanted to irrigate at the same time. During the ‘half water’ turn[28], farmers irrigated the crops that were most in need of water and would probably suffer if they had to wait for the official irrigation turn (at most 11 days).

Table 3.7 System operation over the whole summer period

DATE	*IRR. INTERVAL*	*MEIA ÁGUA /ÁGUA TODA*	*ORDER WITHIN EACH CASAL*
24 June			
	6 days	*Meia água*	a-z >
	11 days	*Água toda*	z-a <
	11 days	*Água toda*	*Salteado*
	11 days	*Água toda*	a-z >
	11 days	*Água toda*	z-a <
	11 days	*Água toda*	*Salteado*
	11 days	*Água toda*	a-z >
	11 days	*Água toda*	z-a <
	11 days	*Água toda*	*Salteado*
29 September 29			

Nowadays, the pressure on water at the start of the summer irrigation schedule has diminished. Irrigation water, originally destined to upstream meadows, could now be applied to the *veiga* area before the 24th of June. However, the ‘half water’ is maintained.

Including the 'half water', three complete cycles of different water flow sequences take place in every summer irrigation period (see Table 3.7).

Water distribution in Vila Cova: rules for equal operating conditions

The rules and practices show that transforming an allocation schedule into distribution practice is a complex process. It requires detailed rules that affect the many factors that influence the division of real irrigation time and the corresponding volume of water. Water losses in canals, travel time of water, the sequence of irrigation turns and the differences between day and night irrigation may all create inequalities in the opportunity of water users to actualise their share of the water.

The Vila Cova rules apparently prevent inequalities among the water users in their individual opportunities to actualise their water shares, notwithstanding the differences in their total water rights[29]. These rules are both inventive and simple. Together they create a continuously alternating pattern of water flows that at first glance seems chaotic but upon closer inspection is neatly ordered.

It is probable that these rules are the outcome of historical conflicts over water distribution that threatened the continuity of the irrigation system. Only some traces to the origins of the rules could be found. For instance, at the bottom of an allocation list from the end of the 19th century, it is stipulated that every user who wants to irrigate a plot outside the *casal* boundaries has to bring back the water to the next field's entrance within the time of his or her own turn[30]. Obviously, this arrangement dealt with a concrete problem in daily water distribution practices. Rules had to be defined to create a more permanent solution for such problems. Over time the solutions have become institutionalised and now form an integral part of every year's practice, thus creating a system of water distribution that is avoids conflict, even though water is scarce.

Water distribution and the individual water user

From the perspective of the individual water user, some comments can be made regarding the suitability of the rules in relation to farming practices. First, several water users find the actual water distribution (too) complicated. Younger water users are not well aware of their turns, at least at the start of the summer period. They have to consult elderly farmers or informal leaders[31] about the periods that they have access to water and they complain about the fragmentation and disorder of their shares.

Second, the water distribution practices require high labour inputs from the water users. Several factors coincide. First, most farmers have time shares within different *casais* and need to show up on various occasions to irrigate their plots[32]. Second, obtaining a water share takes some more time than the time of the share. Although every water user knows the duration of his time share, who is his predecessor and successor, he doesn't know exactly when to start his irrigation turn because of variations in travel times etc. So the water users need to control their predecessors in the *casal* sequence[33]. Generally, three water users are in the field at the same moment: one finalising a turn, another starting to irrigate and a third who is next in the sequence and verifies the time taken by his predecessor[34]. Lastly, since night irrigation is part of the irrigation practice, every third irrigation turn includes hardship and drudgery. Using surface irrigation methods, it is especially difficult to irrigate food crops at night. Therefore water users try to swap these night irrigation turns with others who would have used their day turn to irrigate meadows.

The third comment concerns the rigidity of water delivery and water use. Although water users are free in principle to use the water wherever they want, because water is allocated to a person and not to a plot, it is troublesome and in many cases not worthwhile to transport the water from one location to another distant one. This reduces a farmer's opportunities to accumulate his water shares for plots he prefers, and makes it harder to apply water at frequencies other than the system interval of 11 days. Only farmers with large time shares (about ten hours or more) have enough room to manipulate their shares.

Two factors have increased the flexibility in water use for a number of farmers. First, a number of water-right holders no longer use their shares. As a result there is more water available for the remaining users. At present, only about 50 out of 82 registered water-right holders actually irrigate crops. The water shares of the absentees are used by relatives, friends or neighbours to increase their irrigation time and use the water more flexibly.

Second, investments in other water sources have also increased flexibility. Some larger farmers, who cultivate much land in the tail end of the *veiga* and receive little system water because of channel losses, have invested in shallow wells. These make them less dependent on the system. Two farmers have also invested in storage tanks on their plots, so they themselves can decide when and how to irrigate (e.g. avoiding irrigation at night). Four farmers have recently introduced sprinkler irrigation as an alternative to the more laborious and time-consuming nature of surface irrigation.

Conclusions

The allocation of the communal irrigation system in Vila Cova forms the basis for its water distribution but requires a set of elaborate translation rules that addresses many practical issues. In Vila Cova, rules have been identified related to the start of the summer irrigation season, the sequences among and within the irrigation groups, the distribution of night irrigation and the water losses that occur during the travel time of water from plot to plot. The rules result in a type of water distribution scheme that is clear and avoids conflict. They tend to create equal conditions for all users to obtain the water to which they are entitled.

The detail and variety of rules, which translate the allocation into distribution, point to the complexity of this translation. This complexity is primarily due to the fact that water is a liquid resource, the availability and manageability of which depend on time and space: flows vary over the year and physical conditions may favour or hinder water distribution. Second, the detail and variety also point at the importance of the rules. Water is an essential means of production in Trás-os-Montes and as such subject to conflicts between people. Clear operational rules and mechanisms may constrain illegal use of water to the detriment of others.

The operation of the system is an outstanding example of the endogenous skill-oriented nature of irrigation practices in Trás-os-Montes. The irrigation system was created and developed by local actors in a specific local context. However, socio-economic conditions have changed much during the last decades with as most important effect a scarcity of labour. These new conditions affect the adequacy of the system. Water users mention e.g. as problems: night irrigation, the complexity of water distribution and the high labour input required in irrigation activities. Also some water users mention the possibility to create reservoirs to eliminate or diminish these problems. But which are the needed interrelated changes in the infrastructure (e.g. concerning capacities of canals and reservoirs), scheme water management (e.g. concerning distribution practices adapted to variable daily flow rates) and water application practices (e.g. concerning the labour input adapted to higher flow rates) to make the system more adequate without destroying the actual skill-oriented nature of the functioning of the system? A very relevant question emerges: to what degree is it possible to improve this system so that it responds better to the actual demands of the water users? To this end, which interventions in the actual infrastructure and water management are needed and possible? These questions will be the subject of chapter 7.3 in which it will be shown that a simple improvement in the physical system could result in a far-reaching synergy to improve the functioning of the whole system.

Notes

1 The other core activity, namely the physical reproduction of the system (maintenance), is generally not a critical activity of FMIS in Trás-os-Montes, as explained in Chapter 2.3.

2 It is plausible that the difference in complexity is strongly related to the difference in water availability. The major hydraulic potential of Mountain systems implies the possibility of a more developed, detailed water division, hence to a more complex and elaborated water allocation and distribution. In many High Valley systems the hydraulic potential is so small that the continued division of the small quantity of available water would result in impracticable irrigation quantities.

3 A colleague expressed himself in the following terms 'this system is bound to change' (pers. comm. José Portela).

4 This case study draws heavily on the Final Research Report of Romainho by Eline Boelee (1992). I supervised her fieldwork for her MSc thesis. Together with her Portuguese collegue Maria Cordeiro she was able in a short time to collect very interesting material but unfortunately for reasons of health it was not possible for her to prolong her stay in Romainho. Some additional information I extracted from three research progress reports written by Maria Cordeiro (1992a,b,c) and the copies of two hand-written proposals to change the water allocation schedule in the communal irrigation system of Romainho.

5 Though generally the meaning of *baldio* is communal lands, in Romainho a lot of what the villagers call *baldio*, is privately owned. They refer to *baldio* as to a type of land with shrubs and bushes.

6 Besides that this outlet drains excess water, it supplies also water in the winter period (28 September-23 June) to more downstream users who have also rights of access to this water in this period.

7 JAR: *Junta de Agricultores Regantes*. The constitution of an official irrigators'council is an exigency to be eligible for the MRT intervention program.

8 In this number are included some users from the neighbouring hamlets Muro and Covas. From the last hamlet are the owners of the meadows upstream of the weir (*lameiros em cima de açude*) which have also rights to use the water of the *Corgo de Lamais*.

9 It took the president and the secretary of the irrigator's council about 30 hours to write this complex system of water rights down.

10 One *poçada* (literally 'one full reservoir') is the accumulated inflow to the reservoirs during one such time period.

11 Similar methods to measure time are described in an ethnographic study about the division of water in a system in Minho (Quintas Neves 1965). To indicate the start of the day a coin, the *vintém* is used. That moment is marked by *o ver do vintém*, that is the moment that a person standing straight can observe which side (face or arms) of the *vintém* (twenty value) coin -when put on the floor- is turned to him. The day was divided in 6 periods whose lengths are measured by the time it takes to burn a candle or a half of a candle.

12 For instance, the *Hora de Cortinha* of the *Dia dos Muitos* (see detailed schedule) may be in the morning but then the next turn it will be in the afternoon.

13 The original water allocation schedule is written in Portuguese. That is indicated with an italic lettertype. Necessary comments and explanations are given for each day. The initials refer to the names of the water right holders.

14 Cordeiro (1992c) mentions that outflow periods are slightly different for the poçadas in the day time and night time.

Outflow periods: Three *poçadas* in a day: 2x1.5 + 1x2 (night period) = 5 hours
Four *poçadas* in a day: 3x 1 + 1x1.5 (night period) = 4.5 hours

15 This is indeed not a simple question. In this respect I will mention only some problems. Without a constant regulation the reservoir has a varying outflow thus the first hour of outflow represents much more water than the last hour, that is to say that the first 1800 m^2 receives more water than the following units. This could be eventually compensated for by regulation of the outflow but that is a complicated, sensible and labour intensive process. To avoid a constant regulation of the outflow a plot-based allocation combined with compensatory mechanisms between irrigation turns is the only possibility.

16 That is not to say that in Trás-os-Montes systems no relation exists between the size of irrigated plots and irrigation time but that is not an explicit criterium in water allocation. Only plot-based water allocation leads to a more or less uniform irrigation intensity, but only in an implicit way. A uniform irrigation time per unit area or a uniform irrigation intensity is a typical technical criterion. In some situations, under some conditions this could be a meaningful criterion, for instance in case of monocultures, uniform soils, topography and where there is a controlled water supply. In the case of Trás-os-Montes, where there is a great diversity of crops, soils, topographical situations and a variable natural water supply (water supply decreases as crop water needs increase) then the criterium of a uniform irrigation intensity makes less sense.

This diversity in factors (crops, soils, topography, water supply) alone is already an indication that there is no uniform irrigation intensity. Apart from these natural factors farmers' irrigation strategies are much more diverse. Farmers have many ways to apply water at the field and farm level including spreading out of the irrigation water over a whole plot or various farm plots (under irrigation); or on the contrary concentrating (intensifying) irrigation water on one plot or part of a plot; or varying in the season, when natural water supply is ample to irrigate more intensively than later in the season (e.g. irrigating green maize earlier and harvesting gradually in the growing season, and concentrate the irrigation water on maize for grain production later on); or, in the course of the irrigation period, shifting irrigation water from one plot to another or from one crop to another; or exchanges of water turns or irrigation water against other farming resources etc.

17 This chapter is based on: Hoogendam, *et al.* (1996). Further, I extracted additional information from the excellent research reports of Julia de Carvalho (1994) and Moniek Stam (1993).

18 A very similar set of rules has been met at the communal irrigation system of the village Póvoa de Lila, localised in the municipality of Valpaços. This set of rules was designed by a local priest (Pers. Comm. of Julia de Carvalho).

19 Some of them have invested their savings from earlier emigration in the development of their farms (acquisition of land, farm equipment etc.).

20 Saturday is the busiest day of the week for many households, reserved to implement the most-labour-demanding farm activities.

21 In Vila Cova maize is the basis of bread *(broa)* which is different from most Trás-os-Montes villages in which bread is made of rye. In the farming systems of Trás-os-Montes, rye is normally the most important rainfed crop but it is hardly cultivated in Vila Cova.

22 The proportion of irrigated to total cultivated land in Trás-os-Montes varies between about 50% in the Mountain areas to about 20% in the High Valleys of Trás-os-Montes (see Table 2.2 and 2.3).

23 In many other Trás-os-Montes systems storage facilities exist and are even necessary because of very low source flows which are too small to irrigate with directly.

24 Water in the winter period is also used to irrigate permanent meadows and sown annual meadows in the *veiga* (October to April) and exceptionally for the irrigation of potatoes and maize. Potatoes are planted from the last weeks of March onwards and maize is sown from the beginning of May in the *veiga*. In 'normal' years these crops don't need much irrigation water until June because the soil is at field capacity as a consequence of former rainfall and low crop water requirements in the first stages of crop growth.

25 Additional use of water during the winter is made by the co-owners of two water mills for the production of rye and maize flour. In the past, the mills had priority in receiving water. Nowadays, there is hardly any interference with winter irrigation.

26 This type of land use is called the *campo-prado* or field-meadow system which is typical for the neighbouring Minho region in the west. However, permanent meadow plots in the *veiga* are increasing. A gross estimate is that about one third to a half of the *veiga* is now occupied with natural meadow plots. They are locally called *lameiros de velho* or 'old meadows' (or 'meadows of the old)' because they represent a tendency of extensification of land use, directly linked with a lack of farm labour force. Historically, cultivation of flax for making linen cloths was also important but now only one miniscule field rests. The decline of flax cultivation is linked with the availability of cheap cloths and the diminishing labour force.

27 In 1986 a length of 750 m has been lined in the framework of a MRT intervention.

28 Similar 'short turns' or 'transition turns' have been encountered in other systems (Hoogendam 1988)

29 However this is not only the merit of the organisation of the water distribution. For instance, the available flow rates in the irrigated area diminish considerably going from upstream to downstream (about 25 to 40 per cent dependent on the abstracted river flow). Thus, in the head end of the system is considerable more water available than in the tail end. However from the viewpoint of equitable water distribution, water users do not feel uncomfortable because the majority of the water users have plots in different parts of the irrigated area. Moreover, the tail end of the system is relatively more occupied by the water users with larger water rights.

30 On the note is written in 'old' Portuguese the following rule: '*convina se quando compoz a agua de Rio de todo a que lhe que a tornar para fora de Cazal ou do sitio de donde ella andar; Deve pollo a sua custa na mesmo lugar a onde lhe pertence estar; Para não causar prejuizo nem ao Cazal nem a ninguem: isto e para ella andar sempre na direitura*'. It means that when someone diverts the water of the river outside the *Casal*or the place in which it has to be, he must bring the water back to this place at his own cost in order not to cause harm to the *Casal* or to anybody else. This [rule] is so that the water will always flow the right way.

31 Julia de Carvalho (1994: 78) related that one of them started to study the functioning of the whole system because he felt 'cheated'. One time when he returned from a stay abroad he wanted to irrigate one of his plots. He saw the user before him irrigating and asked this user when his turn ends. This user responded telling him to wait a little bit more. Then suddenly, the water user after him appeared and cut the water off from the first water user. When the 'cheated' water user claimed his turn the last water user responded that he had let his turn pass. From that moment on the 'cheated' swore that he was going to know better than anyone else in the village the allocation and distribution of water in the system. Later on when he returned abroad, he phoned his wife indicating when she had to irrigate.

32 Contrary to the Vila Cova system, other Trás-os-Montes systems exist in which a water user has a water right in one unique period during an irrigation interval (equal time shares, see Chapter 2.4). In this case, much water can be lost for the individual water right holder because of canal infiltration during the travel times between scattered and relatively distanced plots. On the other hand, all other conditions being equal, labour input is lower because irrigation activities of that water user are concentrated in one period per irrigation interval.

33 This rotation sequence is a good illustration of a self-enforcing rule with low transaction costs. An interesting variant of this time control I found in the description of an irrigation system in the region of Entre-Douro-e-Minho (Pinto 1983). In that system is indicated for every irrigation day a person who controls the irrigation time of every user. This person is the last one to irrigate that day. If he is not controlling well the time, it could happen that there is no more time for him to irrigate at the end of the day. On the contrary, in case some water user fails to appear in time, the irrigation time of that user will go to the time controller ('*quem deita o relógio*'). Another interesting control mechanism is mentioned by Dias (1953) for the famous village (in ethnographer's circles) of Rio de Onor and Bennema (1978:66) for Marras. In that village one of the water users had to inspect daily the irrigation system and to check whether grass had been stolen by inhabitants of a poor neighbouring community. In order to demonstrate that he had really walked to the farthest point, the villager whose turn it was had to bring the *caiato* – a wooden hook, hung up on an oak branch at that farthest point by the villager whose turn it was the day before- to the house of the village policeman. In Marras there were two hooks, respectively numbered with an I and a II; these hooks must be hung up alternately. This was an effective mode of control except when somebody managed to mislead the village policeman by showing a well-made copy of a *caiato*.

34 A similar behaviour is described by Portela (1988).

2 foto's

4 The Role of Irrigation in the Modernisation and Transformation of Traditional Farming

In Chapters 2 and 3, I have described the functioning of the FMIS in Trás-os-Montes and the context in which they are embedded. In this chapter I will describe in more detail the socio-economic conditions of the rural sector in Trás-os-Montes and the profound changes that have taken place in the last decades. I will also pay attention to the particular analysis made by state institutions of these conditions and changes and the development interventions based on this analysis. Many of these interventions have been initiated and implemented in the framework of the Trás-os-Montes Integrated Rural Development Project (PDRITM). This program and its successors aimed at the modernisation of the agricultural sector. In order to attain this objective the program was focussed on stimulating a development based on exogenous elements, introduced from outside. In the exogenous development model, locally available resources are considered superfluous or even constraints for development, so that they need to be replaced. This is opposed to the concept of endogenous development which builds further on local resources, in other words, the existing physical, human and social capital (see Chapter 1).

In the modernisation of the agricultural sector, PDRITM attributes an crucial role to irrigation. This chapter describes the discourse of PDRITM in relation to the role of irrigation in agricultural development.

4.1 Trás-os-Montes: The historial and cultural context

Trás-os-Montes is commonly presented as the most depressed, marginalised region of Portugal. Relatively isolated[1], it has a lack of social and economic infrastructure (education and health facilities, roads, markets etc.). Employment opportunities in Trás-os-Montes outside agriculture are very limited. Industries are nearly absent. Incomes in the farming sector are low. In terms of per capita income from farming in the European Union, Portugal stands as a extreme case. According to an official EU-source (RICA), more than 80 per cent of the surveyed farmers in Portugal earn less than 4000 ECUs per year (CCE 1992:48, cited in Portela 1993).

In Trás-os-Montes, in 1970, more than 70 per cent of the labour force was engaged in agriculture (Census 1970). In 1980 this parameter had decreased to about 60 per cent (Census 1980). Farming is still the principal activity of the majority of the active population, though the role of farming has changed considerably in the livelihood strategies of rural households.

Historically, social stratification based on unequal access to land resources was sharp and abject poverty was widespread. Untill the 1950s some landless groups were hit by periodic food shortages and seasonal hunger. State interventions by the Salazar and

Caetano regimes from the 1940s to 1974 affected the livelihood of many rural people. The forestry policy of the government took a lot of the communal moorland area (*baldios*) out of the control of local communities, which principally affected the poorest, landless people. In many cases their source of subsistence in herding sheep and goats or in the cultivation of small plots in the *baldios* was cut off. Also cattle pasturing was severely restricted.

These unfavourable conditions combined with the strong need for industrial labour in West Europe, led to the massive emigration from the rural zones since the late 1950' s. The population of the district of Vila Real diminished by about 19 per cent between 1960 and 1981. According to more recent data from the 1991 census, the population of Trás-os-Montes had diminished by 50,000 people, i.e. by more than 10 per cent of its population[2] in the period between 1981 and 1991. In some rural zones decreases of up to 30 per cent took place over the same period (Garcias 1991; INE,1991). At the same time the share of the older people in the total population was increasing[3] and social payments tended to become economically significant for many households.

Migration is referred by many people as one of the (historical) events which had and still has most impact on their social and personal life. They talk often in terms of 'after' and 'before' (migration). Such massive emigration[4] had - and still has - a profound and contradictory impact upon the local communities and transformed the social and physical landscape in many aspects[5]. On the one hand, living standards in general have improved considerably. On the other hand, the local way of life is deeply affected and the viability of village life is threatened, also in terms of culture and identity. Some villages mainly have old people left. Social infrastructure is underutilised. Some village schools only have one teacher for only one or two pupils.

The exodus of farmers and agricultural labour force has made the agricultural sector decline even more. Farming has been profoundly affected. From the most common and often only way of living it is now only a part of the livelihood strategies of the households. Farm work has become increasingly feminised[6]. Extensification of landuse, that is to say the tendency to cultivate the best plots (relative to distance, quality of soils, availability of water etc) and to abandon others that are less favourable, is a common phenomenon (see Table 2.3).The importance and production of staple crops (rye, potatoes) declined while livestock production has gained more importance and became the principal activity of many farm households.

On the other hand, in the 1970s and 1980s many returned emigrants[7] invested their savings in the building of a house, land purchase and other farm investments in order to start new farms or to develop their old ones. Nowadays returned emigrants are mostly pensioners who still invest a part of their savings in land purchase and other farm investments (especially tractors) although most of them do not intend to build up a viable, commercial farm but to create security for old age and for their family[8].

4.2 The Trás-os-Montes Integrated Rural Development Project

To improve the unfavorable conditions as perceived by many people, to stop human desertification of the region and to respond to the crisis of the Trás-os-Montes rural areas, the Portuguese government launched the Trás-os-Montes integrated rural development project (PDRITM). From Portugal's entry into the European community in 1986 the government formulated some more general purposes such as the recuperation from the structural backwardness and the improvement of the competiviness of the Portuguese agriculture in relation to the other member countries of the EEC.

The PDRITM project has been prepared since 1977 and was implemented since 1984. The Portuguese State negotiated the financing of PDRITM with the World Bank. From 1987 on, other assistance programmes, such as the Specific Programme for the Development of the Portuguese Agriculture (PEDAP) have also been implemented with the support of EU-funds reserved for the structural adjustment of Portuguese agriculture and the development of European marginal areas. These programs are conceptually similar to and a continuation of the PDRITM program.

The general objective of the PDRITM was to increase the income of the rural population and to improve their living conditions. The project included a public component (construction and improvement of social infrastructures like roads, schools, domestic water supply etc.) and an agricultural component. The PDRITM-diagnosis of the problems in agricultural development in Trás-os-Montes can be summarised as *a lack of modernisation* in the sector as a whole. Both technicians of the Trás-os-Montes Regional Directorate of Agriculture (DRATM) involved in the project and the project documents mention as the main obstacles for "progress" (World Bank 1982; Vilhena de Gusmão 1985; Gusmão *et al*. 1987; PDAR 1991):

- the structure of the landholdings (too small size of farms with many dispersed plots);
- the low production and productivity of traditional farming systems caused by poor adaptation to agro-ecological conditions, irrational use of available resources (labour, land, water) and a lack of diversification in light of the dominant 2-year potato/rye rotation;
- the nature of the farming population, formed by tradition and characterised by low technical skill, illiteracy, ageing and isolation.

This diagnosis, repeated again and again in mainstream Portuguese policy and technical circles[9], basically boils down to the idea that traditional agriculture has run out of development possibilities. This type of diagnosis strongly echoes the Schultz thesis (1964) that traditional agriculture has reached its 'technical ceiling'. Consequently, endogenous farming systems based on the use of local resources (natural resources, local knowledge and skills, social resources and networks) need to be replaced by exogenous farming patterns based on technology and resources from outside.

The project aimed at establishing a basis for technological progress in order to modernise the regional agricultural sector. Within a broad framework of project activities, PDRITM stimulated the specialisation of agriculture and the introduction/ development of exogenous farm development patterns in the various agro-ecological zones of Trás-os-Montes[10]. In the agro-ecological zones of the Mountains and the High Valleys, traditional mixed agriculture in which crops and animal production are combined, had to be transformed into intensive and competitive animal husbandry farms. Vilhena de Gusmão (1985:182), one of the main architects of the PDRITM programme, refers to traditional agriculture as:

> *'a type of mixed, relative extensive agriculture with a manifest disadjustment of the use of the soil in relation to its real potentialities. The crop and the cattle husbandry, however existent in the same farms, are not integrated in a satisfactory way. This because on the one hand there is the arable land fundamentally occupied by potato and rye. On the other hand the cattle husbandry is too much disconnected from the arable land and based on the use of lameiros and the spontaneous pasture from the baldios and uncultivated areas'* (Vilhena de Gusmão 1985:182).

The proposed solution, *increased fodder production on arable land*, was seen as the basic condition for such a transformation, i.e. intensified cattle-raising, both for meat and milk production[11] (Vilhena de Gusmão 1985:186).This also meshed well with the government goal of expanding pasture-based meat and dairy production in order to improve the foreign trade balance through the substitution of production systems that rely on subsidised imported feed grain (World Bank 1978, 1982).

With regard to the agricultural component of the PDRITM, the most important activities include:

- rehabilitation and improvement of traditional irrigation systems
- the construction and installation of collective village milking parlours (SCOM).
- provision of credit for farm investments (purchase of livestock, farm machinery, seeds, fertilisers and other inputs, construction of livestock shelters) linked to the adoption of new cropping patterns and technological packages pre-defined for each agro-ecological zone (*áreas de tratamento homogéneo*)
- improvement of the agricultural services, extension and applied agricultural research.

The *core* of the development proposals of PDRITM and the later EC investment grants ("797" projects) is the creation and development of viable agricultural enterprises through the implementation of pre-designed changes in production systems (*propostas de reconversão*), only slightly different for the agro-ecological zones of the Mountains and the High Valleys. These new production systems in many aspects signify a rupture with traditional production systems and represent exogenous farming patterns. In these patterns local resources (e.g. the *baldios*) are increasingly replaced by resources from outside (e.g concentrate).

It was assumed that the adoption of these models would rationalise and intensify the use of resources, diversify production and increase production and productivity. The short term aim was to increase the income and the well being of the farmers. The aim in the long run was to make a basis for necessary structural changes, principally with respect to the small farm structure so as to enhance competitiveness of the Portuguese agricultural sector within the European Community.

The major development on farms adhering to the PDRITM farm proposals would be a change in cropping pattern, namely from a two year cereal/fallow or potato/cereal rotation[12] to a four year potato/cereal/two years of temporary ryegrass-clover meadow rotation (Vilhena de Gusmão 1985:185). The resultant fodder production would allow to more than double the quantity of cattle[13] (Vilhena de Gusmão 1985:186). An increase of water availability and irrigated area[14] was assumed to be a basic condition and/or priority action for the implementation of new farming models, the introduction of new technology (e.g fertilisers, hybrid maize) and improved agricultural practices. Intensive dairying would be developed, based on fodder production from irrigated temorary meadows and from improvements in unirrigated pastures of the farms involved [15]. Each model comprised a set of well-defined proposals including ideal crop rotations, an agricultural technological package (e.g. introduction of Holstein-Frisian cattle for milk production in the High Valleys and cattle for milk and meat in the Mountains) as well as an indication of farm investments to be considered (World Bank 1982; Vilhena de Gusmão 1985; MACP/DRTM 1982).

Because the project would attempt to induce some fundamental changes in farming systems that are rooted in long traditions of the farming population, it was foreseen that the task of inducing these changes would be difficult (Gusmão *et al*. 1987). The PDRITM programme attempts to solve this problem in two ways: first, improvement of agricultural services, extension combined with agricultural applied research and second, providing particular favourable credit terms for financing on-farm investments like the purchase of livestock, farm machinery, seeds, fertiliser and other inputs, construction of livestock shelters (World Bank 1982; Vilhena de Gusmão 1985; MACP/DRTM 1982). At the same time eligibility criteria for credit facilities and subsidies were defined. Only farms meeting minimum requirements, particularly in terms of size (a minimum farm acreage of 6 ha) and availability of irrigation water (50 per cent or more of the farm area irrigated), could become involved in the Project. These eligibility criteria excluded the majority of the farmers[16]. Later on these projects have been succeeded by the EEC ‘797’ projects[17] which are conceptually the same. But access to these ‘797’ grants is still more selective regarding the scale of production. Moreover, farmers had to belong to the categories of full time farmers or ‘young’ farmers.

In the PDRITM approach, the adoption of the new farm models was assumed to be strongly related to the successful performance of other project components, particularly the implementation of collective milking parlours at village level (SCOM), the rehabilitation and improvement of traditional irrigation systems (MRT) and other irrigation interventions.

The irrigation interventions were considered as a key factor to PDRITM’ s progress[18], a pre-condition for the implementation of the technological reconversion proposals in the agro-ecological zones of the Mountains and High Valleys. In the perspective of the PDRITM planners the transformation of rainfed areas to irrigation would be the principal motor for the whole process of agricultural development (Portela 1987:9)[19]. Water was considered as a basic factor facilitating a more widespread use of modern agricultural technology. In their view, the irrigation component was strategic, especially in creating favourable conditions for farmer’ s adoption of the predesigned farming models and in the realisation of the proposed technological packages, including changes in crop rotation. Intensive dairying could only be developed based on fodder from irrigated crops and pastures combined with improvements in not irrigated pastures.

The idea underlying the interventions was that these would yield substantial quantities of (incremental) water and additional irrigated areas in order to make possible a considerable increase of fodder production. Assuming available irrigation water could be increased it was expected that the majority of the farmers could implement the proposed crop rotation (Vilhena de Gusmão 1985:185) wich implies a reconversion of about 50 per cent of the rainfed arable land in temporary meadows, mainly irrigated.

The government created and supported through the PEDAP program three different irrigation intervention subprogrammes:

- Implementation of new collective irrigation perimeters (NRC[20]).

Twelve schemes have been planned (Pinto 1991) the first, of which (Curalha) started to function in 1992 and the second (Gostei) was initiated in 1993. PDRITM and PEDAP focus more and more on such schemes for the development of viable farm enterprises (Portela 1991) because it was expected that in these schemes better conditions could be created to induce changes in cropping patterns and agricultural practices. The process of planning, design and construction of the scheme is essentially an external intervention with nearly no involvement of those who will be the future water users. This intervention will create new water by storing excess winter precipitation. In these schemes, summer water availability will increase enormously as the result of the construction of medium-sized dams and storage reservoirs with capacities in the order of a million m3 per scheme, sufficient to irrigate somewhere between 100-300 ha. The (economic) viability of these schemes was based on the assumption of a considerable change in cropping patterns (*reconversão cultural*) which in reality failed to occur (Baptista 1999: Chapter 6)

- Creation of individual irrigation facilities (PRI[21]).

Until 1991, 152 projects have been implemented in Trás-os-Montes (DRATM 1992). On a national scale the development of individual water resources, often combined with an electrification component, has been stimulated and subsidised in the framework of the PEDAP program[22]. Mainly larger farmers, often involved in '797' projects, are benefitting from this component.

- Improvement of traditional irrigation schemes (MRT).

Until recently, this intervention programme has been the most important in terms of impact. It is a national programme[23] and has been implemented mainly in the Northern and Central parts of Portugal. By July 1992, about 150 irrigation systems had been improved in Trás-os-Montes covering an estimated area of 7500 ha (Portela 1992), and another 100 schemes had been scheduled before 1996.

The rehabilitation and improvement of existing irrigation systems was the first irrigation intervention of the PDRITM program. It was considered a basic condition for agricultural development in Trás-os-Montes and a key factor to PDRITM's progress. Later on, when the contribution of the MRT intervention to the transformation of traditional agriculture turned out to be disappointing, the State shifted more to other interventions as PRI and NRC for reasons already mentioned.

In this thesis I will focus on the MRT interventions.

4.3 Improvement of traditional irrigation: Philosophy and activities

The MRT intervention programme is a typical example of a modernisation approach based on linear cause-effect relationships. The specific objective of the MRT intervention was to increase the availability of irrigation water[24]. It was expected to reduce water losses from 50 per cent to 20 per cent, increasing by about 60 per cent the amount of water available during the summer period (World Bank 1982; 1989). The indicated values in this statement are pure guesses: about water losses in the irrigation channels no hard data were available at that time (Chapter 6 will discuss this issue more in detail). In the view of the PDRITM planners it was assumed that this increased water supply would yield a substantial increase of irrigated area and agricultural production. It was expected that more water will induce farmers to switch to more productive crops and varieties, more inputs, improved cultivation practices which would particularly contribute to enhanced fodder production. This subsequently would lead to higher animal production, to an elevation of the farmers' standard of living[25] and in so doing ensure progress in the rural areas.

However, to mention only one problematic aspect of this reasoning, it was not taken in account that this intensification of land use would mean the need for more labour which is hardly available. Probably it was believed that in traditional agriculture hidden unemployment is a general characteristic according to a general assumption used by many economists and agricultural planners.

The other components and activities of the PDRITM were necessary to induce the above mentioned changes. The MRT had to contribute in creating favourable conditions for the introduction of new farming models. In the project documents, the envisaged crop rotations in these farming models are described as a major development on farms within the proposed irrigation schemes (World Bank 1982:17). The strong linkage between the implementation of the new farming models, new technological packages and the MRT intervention also appears from the fact that the envisaged cropping pattern of these farming models, which is a determinant for the required irrigation water supply in the summer, has been a basic element in the technical design (e.g. dimensioning of canals and reservoirs) of the improved irrigation systems.

For the definition of its practical strategy, the MRT component could not build upon a thorough knowledge of the functioning of the village irrigation systems. Nevertheless, it was realised that interventions would be most fruitful if they were – as much as possible – adjusted to existing situations. The basic idea was not to build a new system, but to improve present infrastructure. Another principle of intervention was not to interfere in the water management of the schemes, since this would probably cause social conflicts and problems in future implementation and management of the systems. These guidelines are clearly inspired by technicians in the regional institutions with first-hand knowledge about the reality in the villages acquired by local origin and experience.

In the MRT intervention the concept of 'improvement' principally signifies reduction of water losses during storage and transport. The main improvement activities have been the lining of earthen channels, impermeabilisation of reservoirs, (re)construction of intake structures and construction of field inlets (slide gates equiped with steel plates). From the second semester of 1983 until March 1990, improvement activities were implemented in 116 irrigation systems covering an area of about 5700 ha with an average area of about 45 ha per system (Portela 1990:3). In this period interventions have been realised in 125 intake weirs, 119 reservoirs and 181 km of channels (Portela 1990:4). Among the improved FMIS, the length of the main canal ranges from less than 500 m to 3.5 km. Out of a sample of 55 systems, there are 18, 11 and 5 respectively in the 500-1000 m, 1000-1500 m and 3000-3500 m ranges of the length of the main canal. Investment costs have been low (Portela 1990:3), from an average of 60 contos/ha[26] for the first 31 improved systems (1983-86) to 140 contos/ha for the last 25 improved systems(1988-1990). In most villages improvement activities have been limited to the communal irrigation system in spite of the growing awareness of multiple irrigation water sources.

Guidelines for implementation

The Regional Directorate of the Ministry of Agriculture, Division of Soils and Hydraulics (DSEA) bore the final responsibility for the selection and design of the system improvement and the supervision of their implementation. In practice the water users and/or the local *Junta de Freguesia* file a request for the improvement of the system. The selection of the systems to improve has been based mostly on technical criteria (access paths, length of the main canal, size of weirs, water flows, irrigated areas, soils, size of village population), biased towards quick implementation. But any specific FMIS could be improved only if 2/3 or more of the water users agreed and subscribed to the improvement contract. It was legally established that an irrigator's council (JAR[27]) should be constituted to organise the water users in the construction work, act as an intermediate (information exchange) between the water users and intervening institutions, principally DSEA, and take responsibility for later operation and maintenance.

Although the public assistance to FMIS is perceived as a catalyst for the modernisation of traditional agriculture, the MRT was restricted to concrete technical improvement activities. Technical staff was instructed to respect local customs and traditions. In improvement works existing canal alignments and plot boundaries were followed, the number and location of plot inlets would not be altered. The functioning of other water facilities like water mills, water reservoirs for animals or washing tanks should not be disrupted. As to water management practices, it was decided to not directly interfere in local rules and habits (water rights, water distribution). Firstly because this was not considered a direct task of a government institution, and second, because changing rules and regulations would imply a lot of conflict-prone issues within the villages. Thus, in spite of the assumption of technicians involved in MRT that the potential of many existing systems was not realised because of faulty management[28] (Gusmão *et al.* 1987), involvement in water management was not pursued. Improvement of the water management in each system was thought to be the task of the newly created irrigator' s councils assisted by the agricultural extension service.

An important element in the philosophy underlying the implementation of rehabilitation works was the direct 'involvement' of the water users (DGEA 1980; Portela 1987b). The idea of popular participation in MRT was based on the tradition of contributions to communal work which is assumed to be a social characteristic of rural Trás-os-Montes (Portela 1987). In the case of MRT, beneficiary water users had to contribute a minimum of 20 per cent of the investments costs[29] in the form of unskilled labour and local transport of materials to the construction sites. This contribution was also claimed to create a farmers' sense of 'ownership' over the rehabilitated irrigation systems and to serve as an incentive for a more rational use of the available water. After improvement, operation and maintenance of the system would continue to be the complete responsibility of the water users. The *Junta de Agricultores Regantes* was supposed to play an important role in this.

Conclusions

In synthesis, the basic assumption of the PDRITM behind the improvement of traditional irrigation systems was the idea that this would create basic conditions for a modernisation of agriculture by making available more water and an improved water use. This would in turn allow for enlarged fodder production and, consequently, for an intensified animal production. Such changes were not understood as merely incremental. They rather imply a drastic and far reaching change in the socio-economic and technical organisation of farming. In the aftermath of improved irrigation possibilities, new farming systems would emerge. To strengthen this process large credit facilities and subsidies were made available in order to stimulate an all-embracing modernisation of agriculture in Trás-os-Montes.

In practice the creation of new farming systems could be noted all over the high valleys and mountains of Trás-os-Montes. They are critically geared to milk production and their development depends heavily on interventions in the supply, allocation and distribution of irrigation water. Apart from the MRT and NRC interventions also many individual irrigation interventions (water sources, pumps, sprinkler systems) can be noted. These emerging farming systems, stimulated by modernisation efforts, contrast sharply with the existing farming systems.

In the next chapter I will analyse the water requirements of these newly induced exogenous agrarian patterns related to irrigation and compare these with the ones of the endogenous agrarian pattern. Related questions which will be dealt within that chapter are: What are the development possibilities of the exogenous farming pattern and what are the consequences of the development of the exogenous agrarian pattern? In chapter 6 I will present a critical analysis of the MRT intervention and I will discuss the question whether the MRT intervention can be considered an adequate response to the modernisation demands of the exogenous farming patterns.

Notes

1 A picture of a strong regional autonomy is reflected in the proverb: *'Além de Marão mandam os que lá estão'* or 'Beyond the Marão (the western mountain chain which forms the limit with the region of Entre-Douro-e-Minho) the people who live there, are in command' . Meanwhile the isolation of the region is relative: Trás-os-Montes has always been an area of more or less intense migration movements.

2 According to census data, the population in Trás-os-Montes -comprising the districts of Vila Real and Bragança- diminished from 442,000 in 1981 to 392,200 in 1991. This is also reflected in the decreasing population density as is shown in the Table below.

Development of population density (Hab./km2)

Year	Alto Trás-os-Montes	Northern Region	Portugal
1981	33.5		
1991	28.9		
1993	28.2		
1996	27.8	166.6	108.2

Source: Census data in Vilas Boas (1999:12)

The human desertification of the interior regions and the hypertrophy of the 'litoral' are two sides of the same coin. 65 per cent of the Portuguese population lives in the coastal strip with only 25 per cent of the total surface area but producing 80 per cent of the Gross Domestic Product and 90 per cent of the industry and services.

3 This is illustrated in the Table below.

Per centage of age classes in the population of Alto Trás-os-Montes e Douro

Year	0-14 year	> 65 year
1960	34.2	6.6
1991	20.7	16.5
Absolute value	Decrease of about 100,000	Increase of about 40,000

Source: Census data in Vilas Boas (1999:16)

4 Migration in Trás-os-Montes is already an old phenomenon. Before the massive migration to West Europe many people migrated to the richer littoral parts of Portugal as well as the Portuguese colonies in Africa, the USA and principally Brasil. It was principally members of wealthier households who went to these latter countries. Taborda (1932:134) mentioned that in 34 years (1880-1913) about 128,000 inhabitants migrated from the province of Trás-os-Montes, equivalent to 31 per cent of its population in 1932. Some emigrants in Brasil made considerable fortunes which they invested partly in Trás-os-Montes. The local bus companies are for a great part their property. The 'Brasileiros', as they are called, frequently contributed to the extension or improvement of the physical infrastructure of their birth places. In the village of Adães the main street is even decorated with the name of a locally-born 'Brasileiro' .

5 This is reflected for instance in the physical structure of the villages. Many migrants started to build *maisons*, very different from the traditional farm houses (combining different functions: habitation, cattle shed, storage of farm production), although mostly the traditional structure (with a cattle shed beneath) is maintained. In most villages one will find now an old centre with traditional farm houses near each other and a *'bairro'* with modern emigrant houses of which a big part is closed during the largest part of the year.

6 Normally, in the first years of migration abroad only the man was going while his wife and children stayed behind. They kept the farm going on. One farmer, having worked 15 years in Germany, told me

that each year he stayed 2.5 months at home: in April to fertilize, prepare and plant the fields and in July-August to harvest and for hay-making. His wife and children always remained at the farm.

7 The majority came from the poorest strata of rural wage workers (*cabaneiros*) and small peasants but most of them left their homes with very strong aspirations and dreams to establish or extend their own farms (Ribeiro 1997).

8 This is for instance reflected in statements like: 'Today my son has a good job but who knows what time will bring'? The agricultural sector in Portugal indeed serves as a safety net. I remember that in 1993 many workers had been fired in the construction industry and that some economic analysts in newspaper comments wondered why this was not reflected in the official unemployment statistics.

9 For instance, in a PEDAP document (1991) this type of diagnosis was generalised for most of the Portuguese regions.

10 These agro-ecological zones are considered basic units, considered homogenous (*zona de tratamento homogéneo*) for the definition of new farming models and development interventions.

11 It was primarily dairy production that was stimulated. According to regional technicians, it was the presence of regional dairy cooperatives (officially farmer's organisations, but firmly related to state agencies) which explained the policy preference for dairy production. The dairy cooperatives were considered to be the most appropriate market agencies for regional agricultural development (Oostindie *et al.* 1995).

12 This two-year rotation schedule has led over time to an infestation of the land with nematodes.

13 In a 1988 pamphlet of the extension service (Baptista *et al.* 1990: Anexo 1) it was claimed that a 8 ha farm with 2 cows and a production value of 578 contos could increase its herd to 6 and a production value equal to 1,330 contos.

14 The introduction of irrigated temporary meadow in the crop rotation on rainfed arable land implies that about 50 per cent of this area will need to be irrigated in the summer. This newly irrigated area corresponds with about 20 (Barroso) till 30 (Alvão/Padrela) per cent of the total farm area in the Mountain areas (calculated from Table 2.2) or an increase of 35 to 75 per cent of the actual irrigated area and still more in the High Valleys. This above-mentioned crop rotation in which 50 per cent of irrigated temporary meadows and corresponding irrigation requirements in the summer is also a basic assumption in the technical design of MRT interventions (see Chapter 6).

15 In the process of implementation of these farming models and the "EEC-797" projects, some other fodder crops, including silo maize, have been later incorporated in the technological package.

16 When it appeared that the real adoption of the new farming models stayed far behind the expectations, the eligibility criteria were adjusted downwards to farms with a minimum area of 3 ha with at least 50 per cent of the farm area irrigated (Baptista 1987).

17 '797' projects are investment subsidies (IFADAP 1993), partly financed by the CEE, aiming at the creation of 'viable' farms. The conditions of access are written down in various CEE regulations (797/85 which was later substituted by 2328/91). The investments could comprise improvements in land resources (e.g. irrigation and drainage), farm buildings, plantations, the acquisition of cattle and farm equipment. Later on also investment in rural tourism, transformation and selling of farm products, protection of the environment and forestry was included. The size of the subsidies depends on the type of investments and of the category of region in which the farm is located (unfavoured regions or not unfavoured regions). The access to these subsidies is strongly conditioned. Most important is the condition of being a full time farmer (*Agricultor a título principal*), defined as a farmer whose income derived from the farm is equal or superior to 50 per cent of the total income and who spends more than 50 per cent of one' s total working time at the farm. In this category are also included the 'young' farmers (between 18 and 40 years) or *jovens agricultores*. Besides the subsidies for a full-time farmer they could apply for some extra subsidies as the first installation grant, another subsidy for

the acquisition, building or improving a house and higher subsidies for farm investments. In a similar way 'young' farmers are attributed higher subsidies in the framework of the PEDAP subprograms if their projects are approved.

18 Gusmão *et al.* (1987:1133) stated that 'In the concrete case of the agricultural part of the integrated rural development of Trás-os-Montes, one of the main aims is the technological development of agriculture, principally in the small holdings, involving a substantial increase in irrigated areas'

19 Vilhena de Gusmão (1985:184) stated that 'the increase of the irrigated area must constitute a priority consideration, has to be the first of the conditions to realise' .

20 NRC: *Novo Regadio Colectivo.*

21 PRI: *Pequenos Regadios Individuais.*

22 Subsidies amount to 70 per cent of each investment in unfavoured zones and 60 per cent in other zones. The subsidies are financed by the Portuguese state in 25 per cent and by the FEOGA (European Agricultural Guidance and Guarantee Fund) in 75 per cent.

23 This intervention was also considered as the most profitable from a macro-economic perspective. This is reflected in the following statements of the World Bank (1978): 'It is more economical to invest lower amounts per unit of land to make full use of the presently underutilised potential of existing irrigation areas' and 'for a more intensive use, the fuller utilisation than at present of the installed irrigation potential and the improvement of small schemes offer favorable short and medium-term prospects' and 'these traditional irrigation schemes are fully utilised within the limits of their generally unimproved water supply. Their main needs are increased water supply during two summer months' .

24 This type of intervention, however now with another name (Beneficiação de Regadios Tradicionais) and forming a component of the PEDAP, has over time not changed in conception. In a recent circular of the Ministry of Agriculture (1998) is mentioned that the rehabilitation of traditional irrigation systems is still understood as 'the avoiding of water losses which actually occur at the level of the distribution network (infiltration losses in the canals), in this way permitting to rationalise water use leading to higher yields, the introduction of new crops and the increasing use of modern technology'.

25 Following this linear reasoning the national coordinator of the PEDAP component 'Beneficiação de Regadios Tradicionais' foresaw that farming households in the improved FMIS would increase their incomes by approximately 50 per cent (Fernandes 1988).

26 Costs are expressed in contos (ct; 1ct = 1000 escudos) at the exchange rate of 1 ct = about 6 US$ in 1989.

27 JAR: *Junta de Agricultores Regantes.*

28 Gusmão *et al.* (1987:1137)) state: 'As these small irrigation systems are collective systems, one considerably important feature is their management. In fact, faulty management is a factor seriously affecting potential production levels. On the other hand, efficient management of collective irrigation systems can be one of the ways of increasing the area irrigated and thus agricultural production. Nevertheless, one should realise that altering traditional methods is a lengthy process, in view of the difficulty in introducing innovations' .

29 The water users could also made their contributions in money terms. In the national PEDAP subprogramme *Beneficiação de Regadios Tradicionais*, which started in 1987, 80 per cent of the investment costs have been subsidised when the systems are located in so called 'not unfavoured' zones (Zonas não Desfavorecidas, corresponding to a small coastal strip from Lisboa to Porto and the Algarve) and 100 per cent of the investment costs are subsidised in the 'unfavoured' zones (Zonas Desfavorecidas: the rest of Portugal). The Portuguese state contributes 25 per cent to these subsidies and the FEOGA 75 per cent (Fernandes 1988).

Foto hoofdstuk 4

5 Irrigation Practices in Contrasting Agrarian Development Patterns in the Northern Portuguese Mountains

In this chapter I will show that local resources in Trás-os-Montes are currently being used in very different and often contrasting ways. I focus on irrigation water which is a scarce and highly valuable resource in this area.

In Trás-os-Montes two categories of contrasting farming styles[1] are found: the so-called 'traditional farming styles' and newly emergent farming styles. The last are principally a product of such modernisation programmes as PDRITM and PEDAP, supported by the EU. Here I will compare the role of irrigation and the different requirements to irrigation (resource use, infrastructure, management) that are enclosed in these two contrasting farming styles.

I will show in this chapter that particular farming styles reflecting the history and traditions of the region, entail irrigation practices that fit very well with local ecological conditions. On the other hand, new farming practices as introduced by official interventions programs aiming at modernisation, introduce a drastic disbalance between the demand for and the supply of irrigation water. I will argue that in the newly emerging exogenous styles, irrigation water is used far less efficiently than in the former, more endogenous farming patterns. Modernisation has been increasingly counterproductive as regards the efficient use of a scarce resource. I will indicate that the consequences of this growing inefficiency and counter-productiveness tend to be obscured. This is due to the externalisation of the implied transformation and transaction costs which are shifted from the level of the farm enterprise to local, national, or supra-national levels. At the same time benefits are also redistributed unequally amongst the farming population.

These statements will be illustrated in the context of a comparison between irrigation practices entailed in traditional (or endogenous[2]) farming styles and farming styles which have emerged as exogenous farming patterns as a result of the modernisation paradigm applied in the mountainous areas of Trás-os-Montes.

My point of departure is the irrigation practice of the agro-pastoral farming system which has developed over time in the mountains of Trás-os-Montes, particularly in Barroso. I have analysed the structure of this particular traditional farming system because fundamental traits of this system are still found in contemporary farming and irrigation practices. This is particularly true of the endogenous development pattern in which meat is produced on the basis of natural forage. This farming style of 'intensive meat producers'or 'intensifiers'is described in more detail by Christóvão *et al.* (1994).

The exogenous farming pattern that has emerged since the early 1980s reflects a deep and many-sided rupture with traditional farming patterns. This is particularly true as far as water use and irrigation practices are concerned. In traditional farming, water demand reflected in irrigation requirements is adjusted to the natural water supply. In the exogenous farming pattern, however, the balance between farm water demand and natural water supply has been disturbed.

Water is a serious constraint on the development of the exogenous pattern of 'intensive dairy farmers' or 'modernisers' described by Christóvão *et al.* (1994). Therefore, in this agrarian development pattern, irrigation interventions are required to increase the amount of irrigation water in the summer. Dams and individual water sources, for example, need to be developed to meet the increasing demand for water. Because the social and economic base of the 'modern' farms in this region is too small, these expensive interventions must be wholly financed or heavily subsidised by the state.

5.1 Irrigation water use in the historically created agro-pastoral farming system

In this section I describe the structure of the agro-pastoral farming system and the entailed logic of natural resource use, particularly the mobilisation and use of irrigation water. This farming system was widespread in the mountainous areas of Trás-os-Montes during the first decades of the twentieth century[3]. The physical isolation of the mountain areas and the absence of other means of living outside agriculture compelled local communities to attain a high degree of self-sufficiency in consumer and reproduction needs. Thus, production for household consumption and reproduction was the basic objective of each annual farming cycle and the major preoccupation in this traditional farming system. In addition to fulfilling basic subsistence and reproduction needs there was often a surplus. The large farmers (*lavradores abastados*) in particular produced a considerable number of marketable meat calves[4].

In the mountainous areas of Trás-os-Montes and particularly in Barroso, natural conditions are relatively unfavourable for agricultural production[5]. The physical environment is characterised by steep slopes, high altitudes, marginal soils and a harsh climate[6] which offers suboptimal growing conditions[7]. Arable land is scarce and up to now there are large extensions of common lands. In 1939, more than 50 per cent of the area of the Municipality of Montalegre was considered *baldio* (Lima Santos 1992:64)

A fundamental condition for the survival and development of this farming system was the availability of abundant wage and exchange labour. This cheap labour force was the result of the socio-economic structure of the agro-pastoral society and a weak external development, which meant that there were hardly other ways of earning a livelihood apart from agriculture. Social stratification and the diversity of farming reflected the highly unequal access to land. The *cabaneiros*[8] or the 'poor' did not have access to enough land to produce cereals (rye[9]) to meet their subsistence needs and to reproduce the means necessary for autonomous farming (seeds and animal feed). The *cabaneiros* depended on the larger farm holdings for the use of such necessities as draught animals, for example. In turn the *cabaneiros* provided the abundant and cheap labour force (often only paid in kind) needed for the great diversity of permanent and seasonal work carried out on the larger farms. The production of charcoal and baskets, seasonal work in other regions (e.g. grape harvest in the Douro valley, grain harvesting in other zones of Trás-os-Montes and in Spain), smuggling and small scale commercial activities offered them some additional income.

The *lavradores* can roughly be divided into two categories: a group of farmers which tended to be self-sufficient in land and labour as far as their consumption and reproduction needs were concerned and the *lavradores abastados*. The former group distinguished itself from the cabaneiros in that it possessed at least one team of draught animals and enough hay meadows (*lameiros*) to feed them in the winter[10]. The *lavradores abastados*, however, had enough arable land to produce regular surpluses of rye and enough meadows to provide winter forage for a number of cattle, much above draught needs[11]. By selling calves, they formed the social group most integrated in market relations.

In 1954 the group of *lavradores abastados* represented 15 per cent of the farm holdings with 48 per cent of the cultivated area. For the group of small autonomous farmers and the *cabaneiros* these percentages are respectively 54 per cent and 47 per cent, and 31 per cent and 5 per cent (Lima Santos 1992:48).

The use of natural resources in the endogenous agro-pastoral farming system

Farming was geared to the optimal use of the locally available natural resources and was adapted to ecological and physical conditions. The farmer's strategy was to make the most of dispersed plots, each of which had its own particular land qualities, soil properties, microclimates and hydrological conditions. On these plots the farmer produced the diverse products necessary for the farm household and for reproducing the farming activity. This led to a specific combination of agriculture and cattle breeding. Hardly integrated in external input markets, farming and its reproduction required cattle for draught power and for manure to maintain soil fertility. The scarcity of arable land obliged the farmer to adopt a pattern of land use that maximised the production of crops for human consumption[12]. Animal feed was secured by different forage components and from the by-products of food crops such as vegetable wastes, rye straw and stubble and maize stalks which were unsuitable for human consumption[13]. Thus, cattle rearing of local breeds[14], the herding of small ruminants and the production of forage crops were based on land resources which hardly competed with the needs of human subsistence.

In this farming system different types of land are assigned particular uses. The most important land types and uses, ordered according to distance from and accessibility to the farmstead, are:

- Small fertile areas (called *linhares, nabais*[15]*, cortinhas, terra natural*) close to the villages, which are used for food production and fresh fodder (*lameiros de erva*). These areas are intensively cultivated and usually irrigated in summer. They are largely man-made, soil fertility and landscape being the result of intensive manuring and terracing.
- Permanent meadows or *lameiros* used for pasturing and -still more important- to produce hay for the winter months. A considerable part of the *lameiros* are irrigated

during winter and spring. They are located upstream and downstream of the summer irrigation areas, near springs and along all permanent and temporary surface streams.

– Rainfed arable lands, principally used for rye production. A considerable part of this type of land is marginally suitable land with shallow, poor soils. Usually the two-year rotation used in these fields was rye-fallow[16]. At village level these open fields[17] are concentrated and normally divided into two roughly equal parts (*folhas*). Cultivation of rye alternates every other year between the *folhas*. The fallow is used for free grazing. A small part of the rye crop is used for grazing and collecting green fodder (*ferranha, ferrã*) in March and April when cattle forage is most scarce (Lima Santos 1992:20; Portela 1988).

– Common lands or *baldios*. Cattle and small ruminants graze on the commons for a large part of the year. Besides being a crucial fodder resource, the commons are still used in the age-old way for collecting firewood and – very important in farming – raw organic material for cattle beds used for the preparation of organic manure indispensable for the reproduction and increase of the fertility of arable lands (E. Portela 1994). The commons are the conversion factory of animal energy in traction, manure and meat. The use made of the commons provides an outstanding example of the local resource base of this type of farming system[18] and at the same time is an indispensable condition for its reproduction.

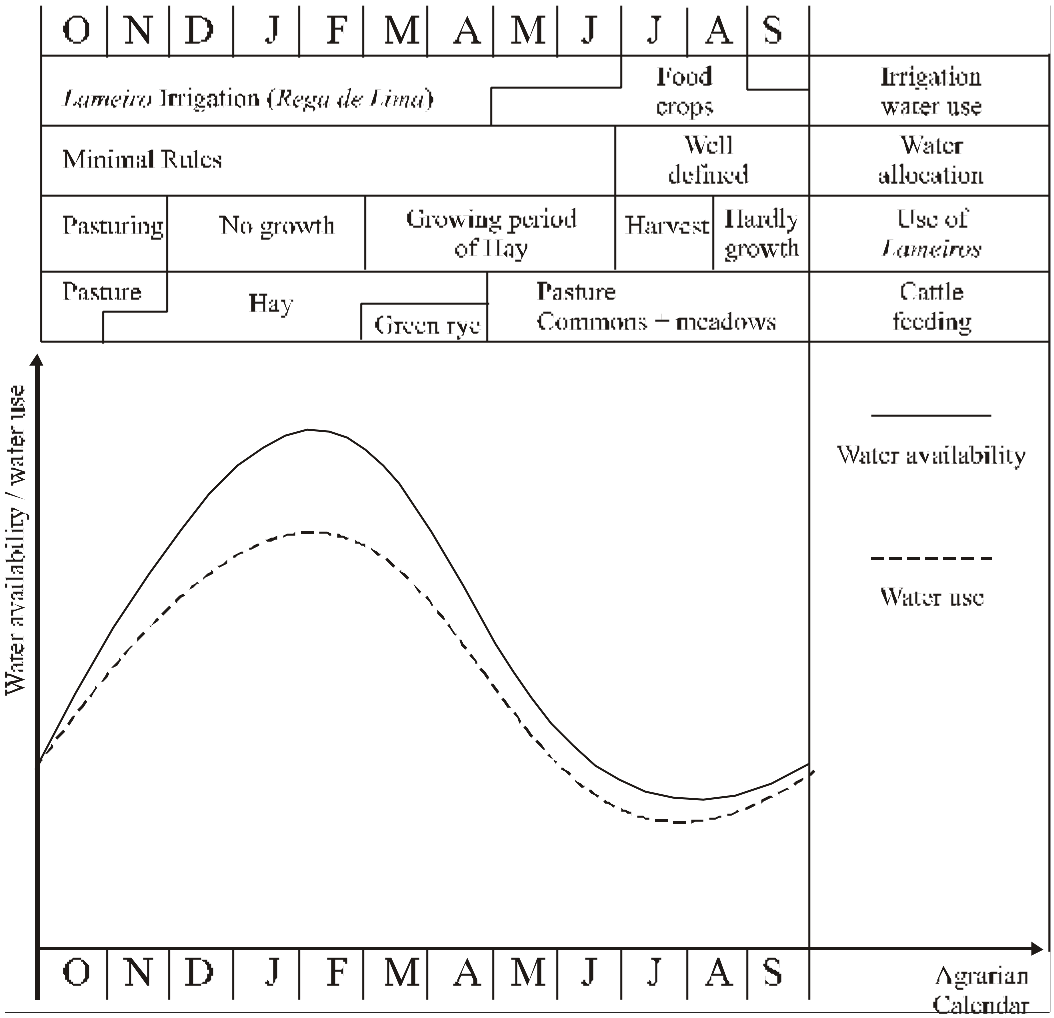
The above mentioned land use types are crucial landscape elements in the spatial organisation of the village territory. They are clearly distinct, concentrated units, constituted by contiguous plots of the same land use type and they have a specific location in the village territory in function of altitude, slope, topography, soil conditions, hydrologic conditions, natural vegetation and man-made features (terraces, soil fertility, irrigation opportunities). As such the agro-pastoral farming system has mainly shaped the typical, beautiful landscape of the mountains and high valleys of Trás-os-Montes[19].

To conclude, the farming system involved an unique social organisation of time and space. It also incorporated a meticulous cooperation based on social differentiation. These two elements allowed for an optimal use of locally available resources. These were steadily developed further and coordinated into a specific farming system. Irrigation slotted neatly into this framework. It related to spatial and temporal organisation, to differentiation and cooperation, and finally it was, and to a degree still is, an essential mechanism in optimising the use of scarce resources.

Irrigation in the agro-pastoral farming system

The logic of the farming system with respect to the use of natural resources also reveals itself in the irrigation practices of these farmers. Farm water use and its specific pattern over time is a perfect illustration of how farmers realised their production objectives by making optimal use of available natural water resources. Figure 5.1 summarises the close correspondance between water availability and water use.

Figure 5.1 Irrigation water use and the agrarian calendar in the agro-pastoral farming system (schematically)



The seasonal availability pattern of natural water resources in Trás-os-Montes is not favourable to the production of arable crops. In Summer, when growing conditions for food crops are good, irrigation water is most scarce. From the logic of the farming system follows that from July to September (summer period) the limited amount of water available should be used exclusively to produce the food crops on which the reproduction of the household and the labour force depends.

From October to June, food crop growing conditions are restricted but coincide with an ample supply of water[20]. During this period, water can be used for other purposes other than producing food crops (mainly potatoes, maize and vegetables), so irrigating the hay meadows or *lameiros* is a useful and profitable alternative way of using water during this period. The maturing of the hay and its harvest coincide with the period of greatest water scarcity (July-August) when water is being mainly used for food crops.

To realise the mobilisation and use of water, numerous irrigation facilities have been constructed by the people of the mountain communities[21]. The communal irrigation systems[22] or *Regadios Tradicionais* are -up until now- the most important source of water in the mountain villages in terms of available water, users and irrigated area[23].

In addition to communal water sources, farmers have also made investments in exploring additional sources of water for individual, family (*herdeiros*) and group (*consortes*) use such as shallow wells and galleries (*minas*). However, water sources development was something of an additional nature and it was not pursued if it was detrimental to the communal systems. In many villages in the Barroso area, it is still strongly prohibited to explore and develop water sources for individual use if this could affect the water available to the communal irrigation systems. However, there is an increasing tendency to undermine these systems and a creeping process of redistribution of available water is taking place, particularly in other areas of Trás-os-Montes.

Socio-economic inequalities are strongly reflected in the unequal access to scarce irrigation water in the summer and the unequal distribution of the benefits of 'winter' irrigation. This is directly linked to the ownership of the *lameiros*: the more lameiros one possess, the more one can benefit from winter irrigation, considering that there is normally no scarcity of water in the winter and spring period.

The irrigation strategies in the agro-pastoral farming system are strongly dependent upon when and in which quantity water is available. Season-dependent water mobilisation and use is also reflected in the spatial configuration of irrigated land resources, the features of irrigation facilities and system management. Field irrigation practices and related labour input, irrigated crops, the location and quality of irrigated plots are adapted to the natural scarcity or abundance of water (as summarised in Figure 5.1).

Lameiros are located along all surface streams and in the vicinity of springs. To some extent, their location is quite independent of soil and land qualities. Critical factors, however, are the proximity of water and the topography: gravity irrigation must be possible.

Summer irrigation makes careful use of the small quantities of water available by applying it to the best lands. Local topography and the localisation of productive sources are crucial factors in the configuration of the summer irrigation perimeters. In many cases, productive water sources are quite far away, and therefore, long supply channels are necessary. In the mountain areas frequently two situations are found: first, the water from permanent streams is channeled or second, the water yielded by a combination of springs localised in upstream *lameiros* and/or *baldios* are canalised to the summer areas (as local people say: '*a água nasce nos lameiros de cima*' or 'the water is borne into the upstream meadows').

In the foregoing I have analysed the structure of the historically created agro-pastoral farming system and its reflection in farmer's irrigation practices. Diversity in faming was based on the differential access to land resources and the differential use of the *baldios*. Farming itself was essentially resource-based i.e. build on the use of abundant labour which exploits local natural resources. Prioritising subsistence and reproduction needs, the farmers' use of irrigation water reflects its availability in terms of time and space. This in turn affects the nature of irrigation management and the configuration of the physical infrastructure.

Fundamental traits of this farming system are reflected in the diversity of present-day agriculture in Trás-os-Montes. The traditional use of natural resources such as *baldios* as an important fodder resource, the use of water in the summer for food crops being given priority when water is scarce and the use of irrigation water outside the summer period on *lameiros* for the hay production that provides the winter fodder are all features of current farming practices. These traits are most clearly seen on the farms that use natural fodder resources to produce meat as will be shown in the following section.

5.2 Recent trends in agrarian development

In the last decades before the 1960s, various internal and external factors have undermined the foundations of the historically created agro-pastoral farming system. In these decades of war, depression and State oppression normal migration movements were seriously hindered contributing to a population growth which was higher than normal. On the other hand the natural resource base available to rural people was seriously affected, as already mentioned in Chapter 4, by the implementation of state afforestation schemes which were established on large sections of the commons. These factors combined with the need for industrial labour in West Europe contributed decisively to the massive migration from the rural zones. In Barroso the population diminished with nearly 35 per cent in the period between 1960 and 1981[24] (Census data in Ribeiro 1997).

Labour scarcity became one of the most important tendencies affecting farming in Trás-os-Montes[25]. The historically created agro-pastoral farming system based on the intensive use of cheap, abundant labour collapsed. The stagnation of agriculture coincided with the rural exodus (Ruano 1986), mainly of *cabaneiros* and small farmers. In Barroso, the *cabaneiros* which constituted in 1960 still 52.3 per cent of the rural population were reduced to some 10.5 per cent of the rural population in 1981 (Lima Santos 1990:3). As the wage labour upon which large farmers depend became scarcer, wages increased[26]. At the same time, labour resources within farming households also decreased considerably. Not only was there a decline in the total number of farming households but there was also a clear shift in their composition. The *lavradores abastados* and *cabaneiros* began to disappear and the number of autonomous small farmers who worked mainly with family labour increased considerably. In the 1970s, many emigrants returned and invested in setting up and developing farms. Between 1960 and 1988, about 70,000 persons returned to Trás-os-Montes from which the majority (89 per cent) occupied themselves in farming activities (Baptista 1999:73)

The changes in the composition of the farming population in northern and central Portugal (North of the Rio Tejo) from 1950 until 1970 are also reflected in the Table below (adapted from '*Projektgroep Portugal*' 1981:141).

Table 5.1 Changes in the composition of the farming population in Northern and Central Portugal

Category	1950	%	1960	%	1970	%
Patrao	118828	10.9	64096	6.4	14105	2.0
Lavradores	238053	21.9	248212	24.6	292260	41.5
Cabaneiros	583741	53.6	533023	52.8	299640	42.5
Family labourers	147759	13.6	162719	16.1	94425	13.4

Remaining	-	-	671	0.1	4385	0.6
TOTAL	1088381	100	1008721	100	704815	100

Sources: Silva Martins (1973:75); INE (1968); INE (1970)
Definitions categories (INE. ,1952-1954):

- *Patrão*: here defined as a farmer that is using wage labour for more than 25 per cent of the needed work force, can be best compared with *lavrador abastado*.
- *Lavrador*: autonomous farmer, category here defined as a farmer who is using principally (more than 75 per cent) no-paid labour of household members.
- *Cabaneiros*: wage labourers
- Family labourer: defined as an adult person who works without wage on the farm.

Today, the economic strategies of rural households in Trás-os-Montes are increasingly influenced by incomes that can be generated outside agriculture[27]. Members of many farm households are engaged in more than one activity and there is usually more than one source of income[28].

Also the nature of farming within many rural household changed. The farming activities are being adjusted to the scarcity of labour. On the one hand this led to an increasing mechanisation of farming activities as is reflected in the sharp increase in the number of tractors and farm machinery, on the other hand it led to an extensification of the cropping pattern as is reflected in the increase of the areas of *lameiros* and chestnut (*castanheiro*). At the same time the importance of arable farming is declining giving way to livestock production which has become the main agricultural activity of many farm households. Farming continues, however, to be based on the interrelations between arable farming and livestock production.

Since 1980, the Portuguese government through such programmes as PDRITM and PEDAP aimed at stimulating the modernisation of the agricultural sector in Trás-os-Montes. New farming styles emerged which embody and express the modernisation project of the state. They contrast with the farming styles which developed from the historically created agro-pastoral farming system and conserve fundamental traits of this farming system.

Cristóvão *et al*.(1994) studied the agricultural heterogeneity in Barroso by means of a regional survey of farm households. The research population is not completely representative of the regional agricultural structure. The study focused on diversity in livestock production and thus excluded farmers with no livestock – in most cases small farm holdings with retired household members. For this reason, the average farm size of the research population is considerably higher than the average farm size in Barroso (13 and 7 ha respectively).

According to the farming styles approach two classificatory dimensions were selected to analyse the qualitative and quantitative data generated by this survey. The first dimension concerns the degree of specialisation in dairy farming. During the 1980s, State and EC-funded interventions in the Barroso region have been strongly oriented to the introduction and stimulation of milk production. Thus, the specialisation in dairy production as opposed to (traditional) beef and meat production reflects the variety of responses to these interventions. Cattle density was chosen as a second classificatory dimension for two reasons. In the first place, it is an indication of the intensity of fodder production on arable land reflecting the use or not of a specific package of new technologies and inputs. Second, it provides an insight into the use of the commons as an essential source of fodder.

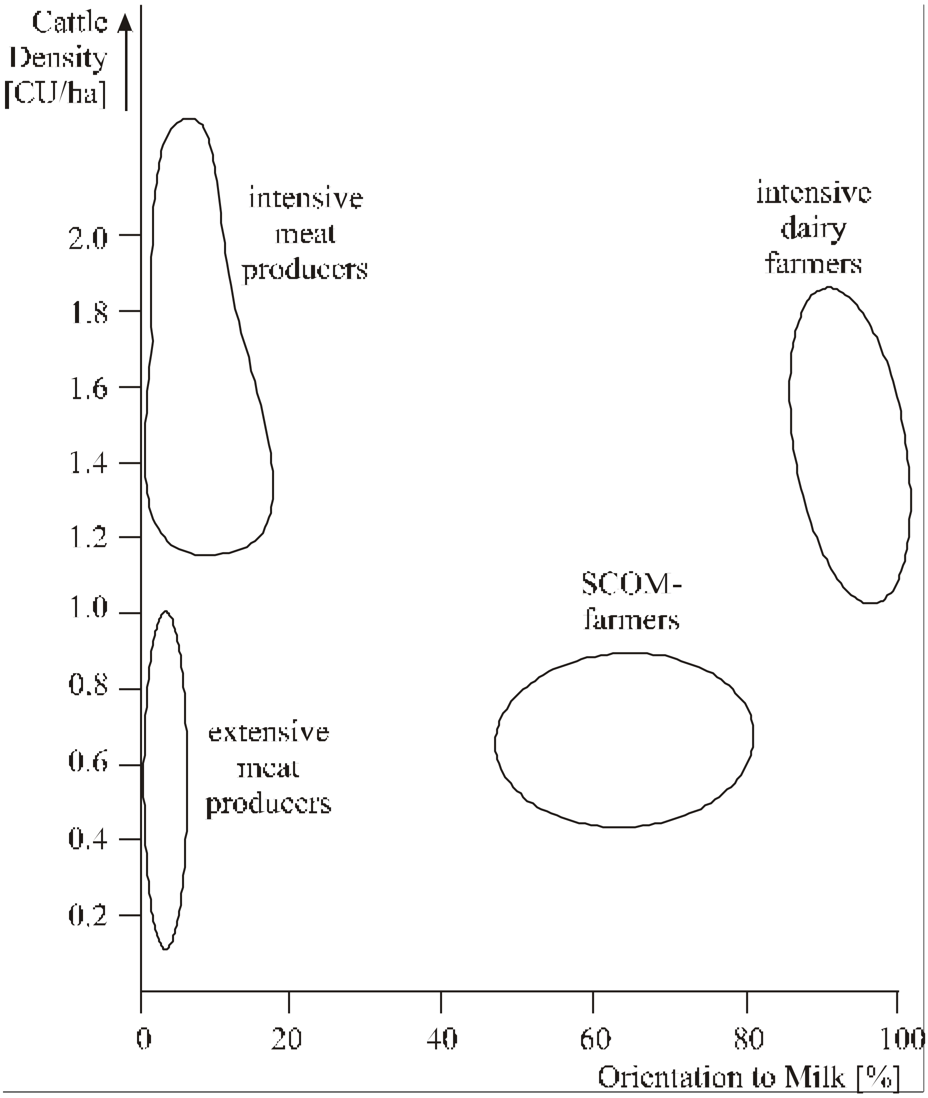
The empirical interrelationships between these two different dimensions made it possible to identify four different clusters. When combined with other quantitative and qualitative data, these clusters can be understood as representing four farming styles (see Figure 5.2)

The extensive meat producers combine a relatively low cattle density (on average 0.8 Cattle Unit (CU)/ha) with an orientation on beef production. This farming style reflects the marginalisation of the 'traditional' farming system in Barroso. Here a decline in the size of the agricultural labour force was accompanied by the gradual extensification of agriculture.

The category of SCOM farmers is an example of a region-specific implementation of dairy production. It is the availability of a *local* response, i.e. the village-based collective milking parlours[29](SCOM) that allows for the integration of new and initially 'external' elements such as dairy production and related exogenous resources into the traditional system of beef production. The introduction of small-scale dairy production in Barroso was not accompanied by a clear intensification, as the relatively low cattle density (on average 0.7 CU/ha) shows.

This contrasts with the characteristics of the 'intensive dairy farmers' or 'modernisers' where a high degree of specialisation in dairy production accompanies a high cattle density (on average 1.2 CU/ha). This farming style is clearly associated with the participation in EU investment programmes that involved a specific package of new technologies including mechanisation, mechanical milking, new stable systems, specialised dairy breeds, sprinkler irrigation, hybrid maize and temporary meadows. Whilst this made it possible to intensify dairy production, it meant also that the *baldios* lost their importance as a local source of fodder. This farming style is characterised by a relatively heavy dependence on external resources for capital, technology, inputs and knowledge.

Figure 5.2 Heterogeneity of farming in Barroso



There is a clear difference in farming practices and fodder production strategies between the SCOM-farmers and the 'modernisers'. SCOM-farmers incorporate important traditional practices in their farming (see also Cristóvão *et al.* 1994). For instance, the hay of *lameiros* remains the basic fodder for the winter period. This is supplemented by other traditional fodder crops cultivated on irrigated and not-irrigated land. In the mountains green rye, fresh grass (*lameiros de erva*), green forage maize and turnips are the most important. It is interesting to note that contrary to Barroso, the SCOM farmers in the High Valleys are following a clear intensification path but different from the 'modernisers'. This intensification path is described in Box 5.1.

Finally, the 'intensive meat producers' or 'intensifiers' combine a relatively high cattle density (on average 1.4 CU/ha) with specialisation in beef production. Here it is not the introduction of new technological packages but the use of the commons which permits a relatively high cattle density[30]. Meat producers say '*O baldio é a nossa força*', the commons are our strength, making it possible to increase the number of cattle well above the limits of their privately owned land. They represent a farming style and an intensification path which is based on the use of local resources.

From this description it follows that the different farming styles are based on and reflect the use of different resources and/or the differential use of the same resources (Cristóvão *et al.* 1994; Oostindie *et al.* 1995). In the following section, I will show that different farming styles also entail different irrigation practices and different requirements with respect to the use of the resource water in time and space.

Box 5.1 The Intensification path of the SCOM farmers in the High Valleys

Contrary to Barroso, in the High Valleys Baptista and Portela (1990) show that cattle densities are higher at small dairy farms using the SCOM than 'modern' dairy farms in the same zone. The fact that cattle density at SCOM farms in Barroso is lower than at similar farms in the High Valleys can be explained by two reasons. First, the average SCOM farmer in Barroso – assuming the same quantity of milch cows per farm- has more land resources available than a similar farmer in the High Valleys, average farm sizes are respectively 12.2 (Cristóvão *et al.* 1994:44) and 5 ha (estimated from Baptista 1989: Annex 1). Second, Baptista and Portela make it plausible that the differences in cattle density is related to the intensive cultivation of annual forage crops on small dairy farms in the High Valleys. In the High Valleys, a greater variety of annual forage crops (green rye, oats, green forage maize, turnip, fodder beet, mixtures of rye, barley, *leguminosae* and grasses, annual grasses) can be cultivated because of a longer growing season and more favourable ecological conditions (higher temperatures). These annual forage crops give higher cattle feed production per ha per year than the temporary meadows and silage maize recommended in the reconversion proposals of PDRITM (Baptista *et al.* 1990). On the other hand, annual forage crops fit in better with the operation of small dairy farms than with the 'modern' dairy farms. This difference between the fodder systems can mainly be explained by the different resource endowments of 'modern' dairy farmers and SCOM farmers. The 'modern' dairy farms have large land and water resources relatively to available household labour. Moreover they have access to capital ('797' projects), credit and relations with government agencies. On the contrary, the SCOM farmers have few land and water resources relatively to available household labour.

Basic features of the High Valleys SCOM farming pattern are: a very labour- and land intensive (two crops/year) cropping system, a finely regulated, flexible type of cropping and agronomic practices adjusted to an optimal use of the small available quantities of scarce water (in August e.g. only for the germination of turnips). So, intensification in this farming pattern is based on increasing the quantity and quality of labour. To name only one relevant difference between the 'modern' dairy farmers and the small dairy farmers: the importance of turnip in the fodder production system. For small dairy farmers turnip is a strategic crop. First, it is a fresh fodder that complements hay feeding. Second, turnip is the crop with the highest growth potential in the winter period. The parts that eventually remain unharvested serve as green manure and could substitute in part for animal manure. Third, turnip -if germinated in August which implies the availability of some irrigation water- is ready to be consumed (jointly with green forage maize and green rye) in the periods of the most scarcity of fodder (*buracos forrageiros*) which occur in November-December and February-March. However, the daily harvest is a very labour intensive activity. That explains why the SCOM farmers with normally 1 to 4 milch cows consider turnips a more suitable crop than the 'modernisers' with 20 or more cows. If the latter group of farmers had the opportunity to choose which implies the availability of an ample quantity of irrigation water, they will by far prefer to

cultivate silage maize and to grow temporary meadows instead of turnips.
It is interesting to note that the SCOM farmers are following a different intensification path than the one singled out in the PDRITM conversion proposals. It shows clearly that one unique development pattern doesn't exist. The conversion proposals of PDRITM and those which are on the basis of the '797'projects for the High Valleys are centred, with respect to fodder production, around temporary meadows and silage maize requiring ample water and land resources but relatively less labour. In the SCOM farms the relative scarcity relations between farm resources are exactly the contrary: land and water resources are more restricted than labour. For these SCOM farmers the cultivation of annual forage crops, requiring more labour but with higher yields and available at times of most scarcity respond better to the necessity of intensification felt by these farmers (Baptista *et al.* 1990)

5.3 Exogenous vs. endogenous farming patterns mobilisation and use of irrigation water

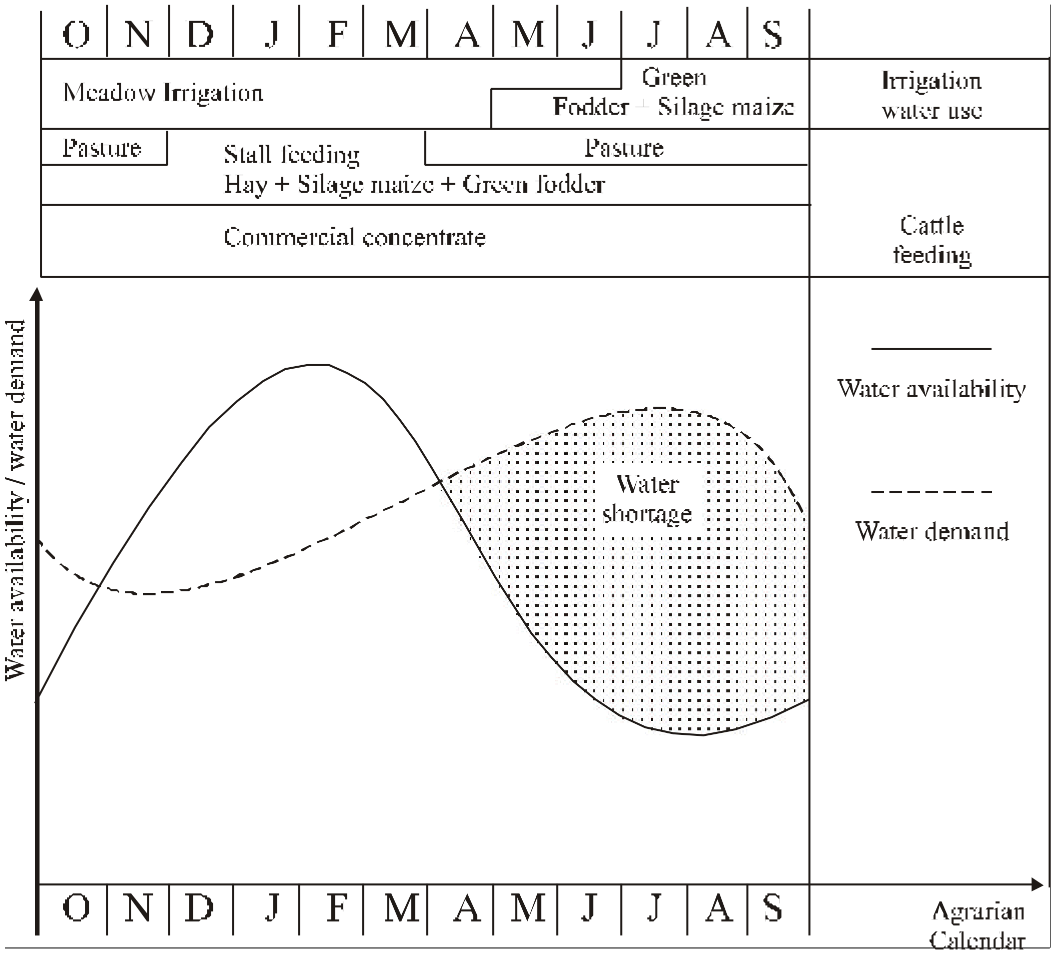
As I have shown before, traditional irrigation practices are intimately linked to the structure of the historically created agro-pastoral farming system. The role irrigation plays cannot be isolated from the direction of agrarian development. In this section I have selected the two sharply contrasting agrarian development patterns in Barroso in order to compare the way irrigation water is mobilised and used. I depart from the diversity of farming identified in the Barroso area by Cristóvão *et al.*(1994). Intensive dairy production ('modernisers') is a clear representation of the exogenous, modernisation-oriented development pattern[31] whilst intensive meat production ('intensifiers') is closer to the endogenous, traditional development pattern.

The two contrasting agrarian patterns employ very different strategies and sets of practices to mobilise and use irrigation water. These strategies are closely linked to differences in fodder production and related cropping patterns. The endogenous pattern makes intensive use both of *baldio* forage and hay produced on the irrigated *lameiros* [32]. Summer irrigation water is mainly reserved for food crops while fodder crops take second place. Concentrates based on rye and maize flour, crop by-products and potatoes are prepared on the farm itself.

The irrigation strategy in modern milk production is very different. A direct effect of the exogenous development pattern is an increased need for irrigation water in the summer. In contrast to the endogenous pattern, *baldio* forage is superfluous on these farms[33]. There are various reasons for this. First, pasturing in the *baldio* involves too much walking for a milch cow and this is detrimental to production. Second, compared to the traditional meat cow (*Barrosã*) the modern milch cow (Holstein-Frisian) is not adapted to the harsh *baldio* conditions. Third, the *baldio* vegetation is not optimal fodder for milking cows.

To compensate for the loss of the *baldio* fodder source, forage crops need to be cultivated in the summer on arable land[34]. To achieve a high milk production, these crops must have a high nutritional content. Silage maize and the temporary meadows are preferred because, with a high volume of external inputs, they produce higher yields and demand less labour[35]. However, to grow high-yielding summer fodder crops, irrigation is essential. Thus, in the exogenous farming pattern, the balance between natural water availability and irrigation demand is weighted in the direction of a greater degree of water scarcity (see Figure 5. 3 and compare with Figure 5.1). Here, *water scarcity appears as a consequence of a specific type of farm development and not as a technical constraint 'an sich'.*

Figure 5.3 Balance of water availability and demand in the exogenous farming pattern (schematically)



Empirical analysis of farm accountancy data

I have used farm accountancy data from 39 Barroso farmers[36] to illustrate the difference in irrigation water use in these two contrasting farming systems. This data came from the archives of the farm accountancy office, *Centro de Gestão*, in Salto.

An analysis of this data (See Oostindie *et al.* 1993) resulted in the identification of various farming patterns in which the already mentioned farming patterns of the intensive dairy producers or 'modernisers' (exogenous) and the intensive meat producers or 'intensifiers' (endogenous farming pattern) are clearly recognisable[37].

In order to compare them I calculated parameters and indicators of irrigation water use. Relationships between the use of irrigation water and farming characteristics as well as between the use of irrigation water and the technical-economic results of these groups were estimated. The calculation model with its variables, assumptions and algorithms can be found in Appendix I. Table 5.2 summarises the results of the calculated irrigation water use parameters in the contrasting farming patterns.

When the data in the table is examined, marked differences in the way the two farming patterns use irrigation water become apparent.

The percentage irrigated farm acreage (parameter a) in the exogenous pattern is about 15 per cent higher than in the endogenous pattern. This difference increases if we compare the average SAU irrigated per cattle unit (parameter k): 0.28 ha/CU in the endogenous vs. 0.69 ha/CU in the exogenous pattern – a 150 per cent difference. The difference still increases if we compare the average irrigated summer forage acreage per cattle unit (parameter j): 0.07 ha/CU in the endogenous vs. 0.32 ha/CU in the exogenous pattern – a 350 per cent difference. This clearly demonstrates clearly that 'modern' farmers are much more dependent on forage produced on irrigable land using scarce summer irrigation water. In comparison to the endogenous farming pattern, the development of the exogenous farming pattern needs an expansion of irrigated arable land. Although traditional irrigated summer areas are now increasingly used for fodder production it is doubtful if the needed expansion of irrigated land for fodder production in the exogenous farming pattern can be fully realised within the traditional irrigation perimeters. Given the lack of good quality lands in Barroso and assuming that these lands are already traditionally irrigated this implies that the needed expansion of irrigated land in the exogenous farm model will be increasingly take place on more marginal lands with poorer, sandy soils which have hardly irrigation facilities, such as land traditionally used for rainfed rye production.

The dominance of the irrigated *lameiros* (parameter e) in the endogenous pattern points to the firm linkage between natural water supply and actual water use. In the exogenous pattern a clear shift towards summer irrigation of fodder crops takes place, making increasing demands on irrigation water when it is most scarce. This becomes still more obvious when the estimated summer irrigation water requirements per cattle unit (parameter p) in the different 'patterns' employed to produce irrigated fodder are compared, on average about four times more scarce water per cattle unit is needed on the 'modern' farms than on the 'traditional' farms.

Another striking phenomenon in the exogenous pattern is the considerable use of silo maize and temporary meadows: about 40 per cent of the summer irrigation acreage (parameter f). These crops are hardly present in the endogenous pattern in which the main irrigated summer crops are maize for grain, potatoes and green forage maize. The traditional use of green rye (parameter h) is largely absent in the exogenous pattern.

In addition, irrigated acreage per cattle unit (parameter j and k) is much higher in the exogenous farming pattern. This farming pattern depends also much more on purchased concentrate[38].

Table 5.2 Comparison of irrigation water use in contrasting farming patterns

Parameters/ indicators	Unit	'intensifiers' endogenous N=12	'modernisers' exogenous N=6
a. % SAU irrigated total	%	56	70
b. % SAU irrigated *lameiros*	%	38	33
c. % SAU irrigated summer crops	%	17	35
d. % SAU irrigated summer forage	%	13	30
e. proportion irrigated *lameiros*/summer forage acreage	-	2.9	1.1
f. % silage maize+temporary meadows/ acreage of SAU irrigated summer crops	%	3	38
Acreage per Cattle Unit			
g. not irrigated *lameiro* (pasture)	ha/CU	0.17	0.14
h. green rye (*ferrã, ferranha*)	ha/CU	0.07	0.01
i. irrigated lameiro	ha/CU	0.21	0.37
j. irrigated summer forage	ha/CU	0.07	0.32
k. total irrigated land	ha/CU	0.28	0.69
l. silage maize+temporary meadow	ha/CU	0.00	0.13
m. use of *baldio* *	h/day	6.2	0.7
Purchased cattle feed per Cattle Unit			
n. purchased concentrate	ct/CU	9.6	34.2
o. purchased forage	ct/CU	0.5	0.3
p. 'scarce'summer water requirements per cattle unit	m3/CU	140	650
q. net income per total irrigated acreage	ct/ha	200	100
r. net income per summer forage irrigation acreage	ct/ha	1350	230
s. gross income per m3 'scarce'summer water	esc/m3	660	210
t. net income per m3 'scarce'summer water	esc/m3	500	110

Notes:
- Values are averages for the two groups of farmers, based on accountancy data for 1989. Naturally there is a considerable variation of these values within the two groups of farmers but for the objective of this study, namely to show the differences *between* the groups, average values are sufficient.
- Abbreviations:
N: size of sample
SAU: *Superfície Agrícola Util* or cultivated farm acreage
ct: *conto.* 1ct=1000 *escudos* (165 esc.=1 US$ in 1989);
CU: Cattle Unit or *Cabeça Normal* (assumption: 1 milch cow=1.5 CU and 1 meat cow=1CU)

* Use of baldios expressed in average pasture time in commons (hours/day) taken from Christóvão *et al.* (1994: Table 2)

If we suppose that feed requirements per cattle unit are more or less equal in the two patterns then it follows that there must be a much more intensive use of *baldio* forage in the endogenous pattern, which is confirmed by the scores on parameter m. The second important forage resource is the irrigated *lameiros* which occupy an average of 75-80 per cent of irrigated land resources (parameter b /parameter a) and about 40 per cent of total land resources (parameter b). The irrigated summer forage (with 10 to 15 per cent of the total SAU: parameter d) clearly only has a supplementary role. For a comparison of resource use in the time dimension between the historically created agro-pastoral farming system and the actual farming patterns, see Box 5.2.

In summary the exogenous farming pattern needs much more irrigated area per cattle unit, hence more irrigation water, especially more scarce summer water (see Figure 5.2).

Box 5.2 Comparison of resource use between the historically created farming system and the actual farming patterns

On the basis of data in Lima Santos (1992:79-82, 245), I made a gross estimate of the average resource use (and its different components) per cattle unit in the historically created agro-pastoral farming system and compared it with the average values in the two actual farming patterns (See the Table below).

Resource use per Cattle unit		*Historically created agro pastoral farming system*	*Actual endogenous farming pattern N=12*	*Exogenous farming pattern N=6*
not irrigated *lameiro*	(ha/CU)	0.20	0.17	0.14
green rye	(ha/CU)	0.06	0.07	0.01
irrigated *lameiro*	(ha/CU)	0.16	0.21	0.37
irrigated summer fodder	(ha/CU)	---	0.07	0.32
commons *		1.82 ha/CU	6.2 h/day	0.7 h/day
purchased concentrate	(ct/CU)	---	9.6	34.2
purchased forage	(ct/CU)	---	0.5	0.3

Note:

* resource use in available commons acreage per CU (Lima Santos 1992:81) or average pasture time in commons (Christóvão 1994:44)

Comparing the historically created agro-pastoral system with the actual endogenous pattern, it is noted that also in the actual endogenous pattern the fodder contribution from arable land and *lameiros* has grown in importance. The same is valid for the purchased concentrates. On the contrary, *baldio* use has somewhat diminished in the actual endogenous pattern compared to the historically created agro-pastoral system. This reflects a marginalisation of the *baldios*. First, during the last decades the *baldio* area has decreased because of forestry development. Second, the quantity of small ruminants, necessary to maintain the grazing quality of the commons, diminished considerably because of a lack of labour for herding.

However the differences in resource use between the historically created agro-pastoral farming system and the actual endogenous pattern are small compared to the differences between the actual endogenous pattern and the exogenous pattern.

Economic returns of irrigation

I will now compare the productivity of irrigation in the two farming patterns in economic terms (see Table 5.2). To estimate the productivity of the irrigated area we link this parameter to net farm income. We can conclude that, on average, for the same net income per farm, about twice as much irrigated land is needed in the exogenous pattern as in the endogenous pattern (parameter q). Linking the net incomes of the farms to the estimated irrigated summer forage area (parameter r), the difference increases by a factor of about 5 to 6.

The productivity of irrigation water can also be estimated. This requires a clear distinction between the irrigation of *lameiros* and summer irrigation. Because water in *lameiro* irrigation is in general not a scarce resource, its productivity is a meaningless parameter. This is not the case in summer irrigation, where scarce water is used. However, the principal difficulty in estimating the productivity of summer irrigation water is the lack of data about the actual amounts of water used. Here I have estimated the total irrigation water requirements for summer forage crops (see Appendix I) according to the empirical cropping patterns of the farms. Using this as a proxy for actual water used[39] can be justified in this case because my main objective is to show that there is a clear productivity difference between the two farming patterns. It is even plausible to expect that the difference in actual water use between the farming patterns is more than the difference in calculated crop water requirements because the crop mix in the exogenous pattern[40] is more sensitive to water stress than the crop mix in the traditional pattern[41].

The calculated water requirements can be linked to net farm income (parameter t). It can then be concluded that, on average, for the same net farm income, four to five times more scarce irrigation water is required in the exogenous pattern than in the endogenous pattern.

In many respects the data presented here contradicts the assumptions upon which the dominant modernisation model is built including the argument that there is a linear cause-effect relationship between increased water use and farm development: "more water yields more and improved forage; this allows for a higher animal production; this raises the productivity of both land and labour and will result in higher farmers incomes. It also gives room for investment and modernising production methods etc.".

To check the results based on the limited farm accountancy data[42] I carried out a comparative model study. Based on the characteristics of the two contrasting farm development patterns, ideal-typical farm models have been constructed which are assumed to be representative for the two patterns. This model study is presented in Appendix II. The results thus obtained point to the same differences in irrigation water use of the two contrasting farming patterns as already obtained by the analysis of the farm accountancy data.

As shown, the most contrasting farming patterns in terms of exogenous and endogenous development embody highly relevant differences with respect to irrigation water use and mobilisation. Main conclusions are:

- The demand for scarce irrigated land per cattle unit is much higher in the exogenous than in the endogenous pattern.
- The requirements of scarce irrigation water per cattle unit are much higher in the exogenous than in the endogenous pattern.
- The input/output relations in terms of economic returns per unit scarce irrigation water are much more efficient within the endogenous pattern.

The explanation lies in particular in the dependency of the 'modernisers' on additional irrigated land resources and new fodder crops like silage maize and temporary meadows. Therefore, the availability of large amounts of water in the period when resources are most scarce, is an absolute necessity in the realisation of this pattern. This requires high investments and/or a redistribution of available water resources at the expense of other farmers. At the same time the commons as a critical source of fodder becomes superfluous in the pattern of the 'modernisers'.

The pattern of 'intensifiers', for its part, produces the necessary fodder for the winter period to a much greater extent on the *lameiros*, irrigated outside the summer period when precipitation and irrigation water are abundant. The utilisation of the commons during the summer period makes it furthermore possible to use the *lameiros* for maximising the production of hay for the winter time. The differences in resource use in these opposed farming styles are synthesised in Figure 5.4.

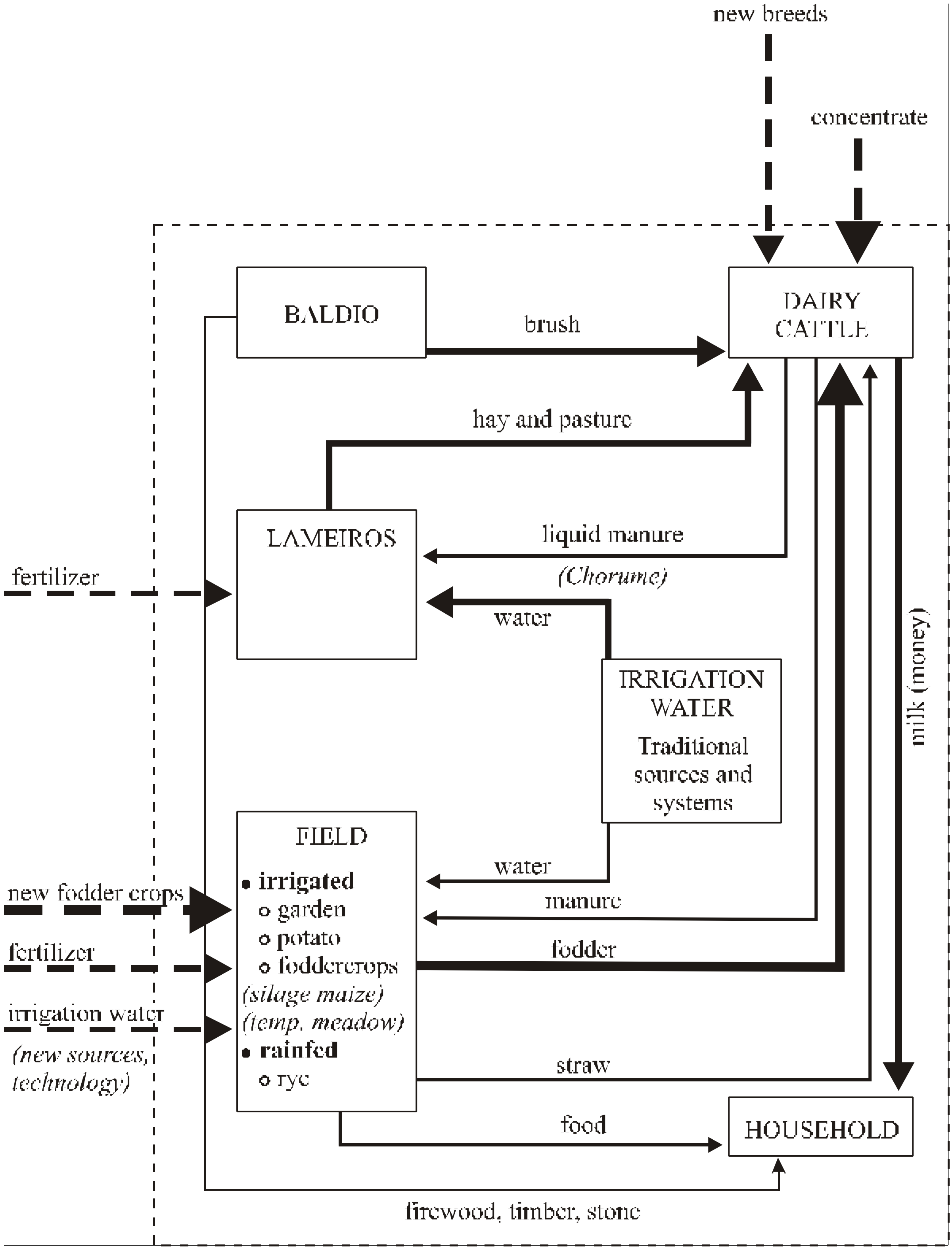
As a result of these contrasting relations between the water requirements and water availability as expressed in the two patterns, the 'intensifiers' depend to a much lesser degree on summer water resources and realise high net revenues per scarce water unit. In other words, in terms of valorisation of (scarce) local resources the specific endogenous pattern of the 'intensifiers' is clearly superior to the exogenous pattern of 'modernisers'.

Hence, modernisation emerges here as containing a tendency towards counter-productivity as far as water as a scarce resource is concerned. This could have far-reaching consequences. First, the possibility emerges that modernisation, by increasing the actual scarcity of the water resources, introduces heavy competition between water users. Second, the development perspectives of the exogenous farming pattern are seriously constrained in relation to the actual irrigation resources. In the following I will discuss these interrelated isues.

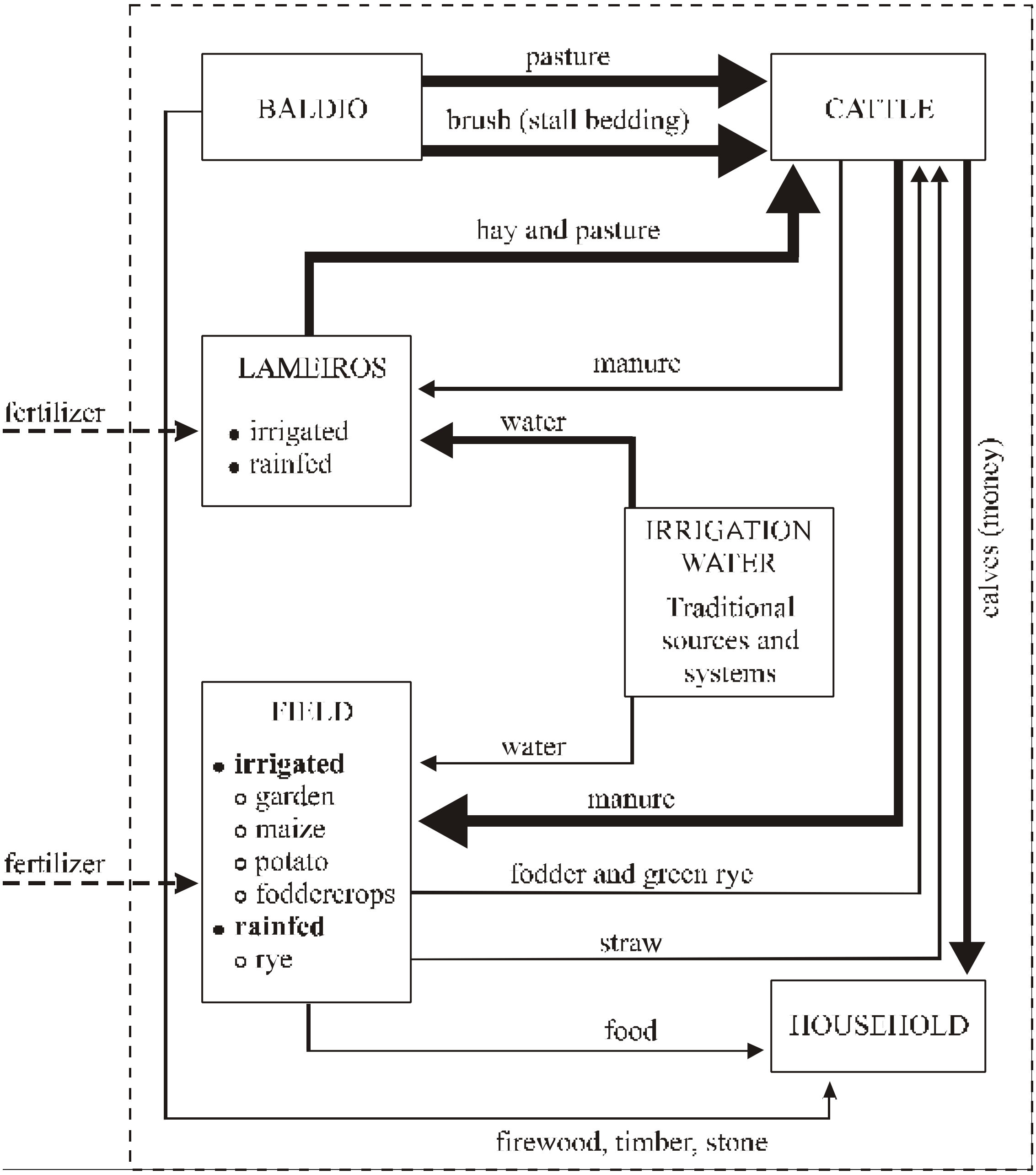
Competition over Scarce Water

The greater water requirements of the modern milk producers can be a serious constraint both at farm and local level. At the village level, the introduction and development of this farm pattern with its need for considerable amounts of water in the summer months competes with the need other farmers have for irrigation water.

Figure 5.4 Differences in resource use between ‘*modernisers*’ and ‘*intensifiers*’



‘Modernisers’



Intensifiers

I will illustrate this by an example which, although hypothetical, is close to a real-life situation. In an ordinary mountain village with 50 resident families (125 persons) I assume an average water consumption per person in July and August of 200 l/day. This value takes into account the extra water needs of emigrants on holidays. For these two critical months this means a total of 0.2*60*125=1,500 m^3. Suppose that an equal amount of water is required for the cattle and assume that the irrigation water requirements for the village's food production amounts to: 0.20 [ha/fam.]*50 [fam.]*2,500 [m3/ha]=2,5000 m^3. Combining household, cattle and irrigation water requirements results in a demand for a net continuous stream flow of nearly 6 l/s in these months. This volume does not take into account the needs of irrigated summer fodder crops. There is enough empirical evidence from source and channel flow measurements taken in 1992, 1993 en 1994 (van den Dries *et al.* 1994; Pinto Marques *et al.* 1994, 1995) to indicate that the majority of traditional communal irrigation systems in Barroso and other mountain areas can hardly deliver this quantity of water during the summer months.

This is a hypothetical example abstracted from the complexity and diversity of local situations, the availability of other water sources and local adaptations to water scarcity but it clearly indicates that the global balance between water demand and water availability at village level in the summer is very precarious. According to my analysis of the farm accountancy data (see Table 5.2), the introduction of one 'modern' farm with 20 milch cows requires about 30 [CU]*650 [m3/CN] =19 500 m^3. That corresponds to a net continuous streamflow of 4 l/s in the two driest months, more than 50 per cent of the vital water needs of the hypothetical village.

Therefore, it can be expected that the policy of support to the development of exogenous farming patterns will lead to an increasing competition for the scarce water resources. This policy stimulates the increasing tendency to construct and explore individual water sources. Taking the increasing demands for drinking water and other uses into account, the consequences of this competition could be an increasing undermining of traditional irrigation systems, over exploitation of groundwater and the 'creeping' redistribution of available water resources. These processes are still felt less in Barroso than in other parts of Trás-os-Montes (in particular the 'milk basin' in the High Valleys[43]) because 'modernisation' has not penetrated there with the same intensity as in other parts of Trás-os-Montes. Also the traditional 'communitarian' institutions in Barroso are not yet as eroded as they are elsewhere.

The exogenous farming pattern: a frustrated development perspective

The exogenous farming pattern involves competition for scarce water and its development is often seriously constrained by the physical lack of water and/or the lack of access to scarce summer water. Water is a limiting factor in the development of exogenous farming. Room for increasing the supply within existing irrigation facilities is generally limited and farmers frequently refer to these problems. In some cases there are no physical possibilities of securing more water and farmers are dependent on the existent communal irrigation facilities.

For instance, a young 'modern' farmer with 20 milch cows in the village of Bosto Frio explained the problems he confronts. The *lameiros* he exploits (all rented) are not providing enough hay for his cattle and he needs to buy considerable additional quantities of hay. The production of silage maize is far under the potential level because of lack of water. He does not have the quantity and quality of fodder which the cows need so they give less milk. Other farmers have already made attempts to find more water by constructing new sources (shallow and tubewells) but these attempts failed. He depends on the *rego do povo* so his only hope of more irrigation water is that this system will be improved. However, this probably will not solve his problem for three reasons: first, water availability at the water source of this system is limited (measured in August 1992, it had a streamflow of about 7 l/s); second, this implies that potential water gains as a result of any improvement are also limited (in the order of 3 l/s assuming canal conveyance losses of 50 per cent of the source flow); third, this additional water must be shared by all households in the village.

In other cases, exploring new sources of water has produced few results. For instance, a young 'modern' farmer with 35 milch cows from the village of Morgade has tried to increase and individualise access to water by constructing one deep well, two shallow wells and two reservoirs. He has only partially succeeded and still depends on the *rego do povo* for the irrigation of 13 plots. Even in this situation, he is strongly dependent on neighbours that lend water to him (*empréstimo do vizinho, pede-se ao vizinho*).

In fact, some farmers find the investments needed to explore new water sources too high or too risky even with the help of subsidies. In 1989, 42 individual water sources were constructed in Barroso with the support of the PRI programme. However, to be eligible for subsidy a deep well needs to yield more than 0.5 l/s. But it is only possible to know this after the tubewell has been constructed and the expenses (about 200 to 300 contos/deep well) have already been made.

The demands for irrigation in the exogenous farming pattern are not limited to higher irrigation water requirements. An expansion of irrigated land for increased fodder production is also needed. This expansion would be best realised in the traditionally irrigated summer areas which are normally the most productive lands in a village domain. However, if the exogenous farming pattern would expand in Barroso, the increase of irrigated land needed for fodder production cannot be realised within the traditional irrigation systems, given the limited extension and scatteredness of irrigated summer areas in Barroso. It can be expected that the required increase of irrigated land in the exogenous farming pattern, if this will expand[44], will have to take place on more marginal lands with poorer, sandy soils that have hardly irrigation facilities, such as land traditionally used for rainfed rye production. These soils have more unfavourable water retention characteristics. Therefore, these lands are far more sensible to dry conditions, field application efficiencies are lower and labour requirements in irrigation activities are higher (smaller application depths, more irrigation turns) than the lands in the traditional irrigated summer areas. That is a first constraint to the expansion of the exogenous farming pattern.

But even if it is assumed that the needed expansion of irrigated land can be realised within the limits of the traditional irrigation systems, there are other constraints. Factors closely linked to the limited water availability in the irrigation systems are labour intensive irrigation practices and the type of irrigation management, aimed at sharing a scarce resource. The successful implementation and expansion of the exogenous pattern implies the need for more water and also for increased irrigation flows. It also requires the imposition of other organisational principles and practices that differ from those present in the traditional irrigation systems. Finally, it assumes a reorganisation of space. In the following I will elaborate on this.

An optimal production of great quantities of modern fodder crops such as silage maize and temporary meadows requires a type of irrigation scheduling in which the crop water needs determine the required water supply in time and quantity, that is to say a specific pattern of irrigation intervals and applied water depths. Moreover, this "optimal" irrigation scheduling also requires a labour-saving potential, for instance in the form of new application technologies and/or higher application flows. In turn, these requirements presuppose access to individual sources.

However, this demand-based or crop-based irrigation is in contradiction with the supply-driven character of traditional irrigation systems. In these systems water users cannot irrigate when and how much they like, but only when and how much the actual allocation permits. In Chapter 2 it was already illustrated how allocation principles determine whether irrigation water can be obtained at the right moment, in the right quantity and a sufficient degree of certainty. In these systems, irrigation practices are bound to working rules reflecting social agreements over sharing scarce resources. This implies that irrigation schedules and distribution sequences are fixed. The length of the irrigation interval, the duration of an irrigation turn and the moment of field application are predetermined by the distribution of irrigation water according to defined water rights (see for an illustration the case-studies of Vila Cova and Romainho in Chapter 3). Some flexibility is possible but involves higher transaction costs such as those involved in negotiating water exchanges and other transactions. Therefore, in the exogenous farming pattern there is a strong tendency to individualise access to water by additional investments, e.g. in the construction of deep wells, reservoirs, acquisition of pumps and tubes etc.

I will illustrate the difference between crop-based and supply-based irrigation at the field level with the help of the irrigation scheduling programme CROPWAT (FAO 1992). This programme shows the effects of supply-based irrigation and the requirements of crop-based irrigation by simulation of the variation of the soil moisture in the root zone during the growing time. It estimates also yield reductions as a consequence of moisture stress. In Box 5.3 I compare these two opposed types of irrigation for a maize field.

From this comparison it can be concluded that crop-based irrigation with a labour-saving potential requires specific combinations of intervals and application depths which in turn require specific irrigation technologies (water sources with constant flow e.g. tubewells, individual reservoirs, sprinkler irrigation or application of relatively high water flows in gravity irrigation).

Box 5.3 Supply-driven irrigation schedule vs. Crop-based irrigation schedule

Assumptions for simulation with respect to field, climate, crop and soil

- Field of 0.12 ha with silage maize
- Soil type: loam with potential root depth of 1 m. (see Appendix III, Table 10)
- Climatic data: ETo and average rainfall of Montalegre (see Appendix III, Table 1)
- Crop; silage maize (see Appendix III, Table 8) ; planting date: 15/5
- field at headend of system (canal conveyance losses nil)

Supply-driven irrigation schedule: assumptions

- start of summer irrigation in FMIS: 24 June
- length of irrigation interval: 20 days; first irrigation: 4 July (in the middle of the interval)
- water right for this plot: 2 hours/20 days
- Source flow during summer irrigation season (see Appendix III, Figure 1)

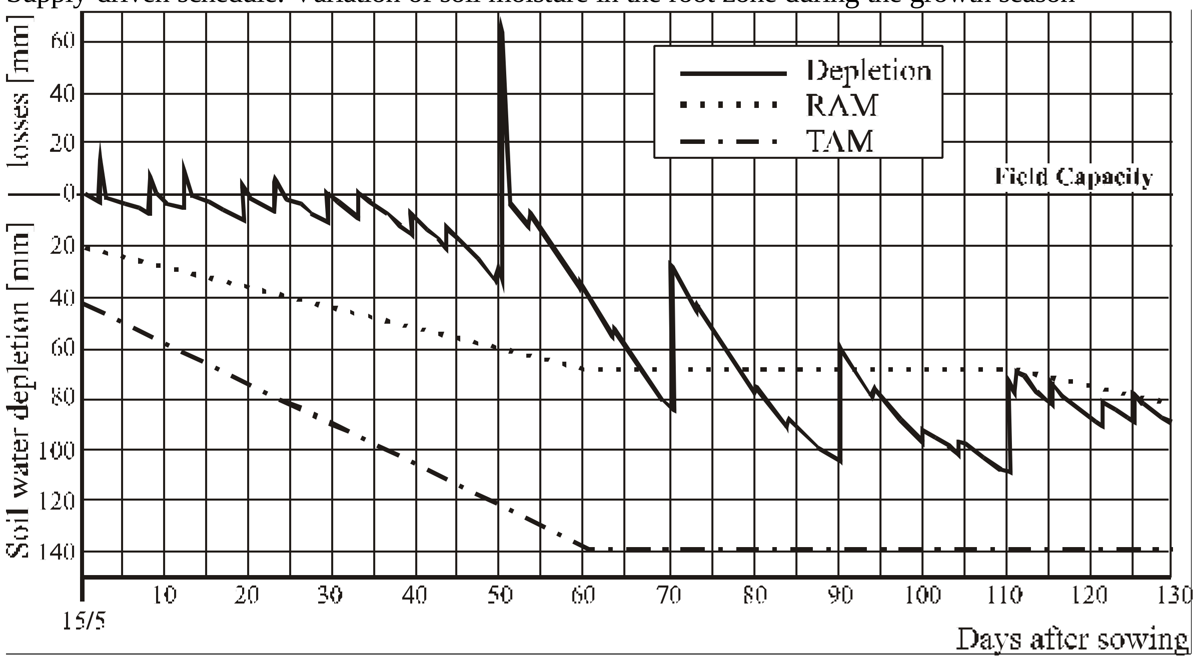
These assumptions result in the following combinations of irrigation dates, source flows and irrigation depths

1) 4–7 (day 50)	16 l/s	96 mm	3) 13-8 (day 90)	7 l/s	42 mm
2) 24-7 (day 70)	9 l/s	54 mm	4) 2-9 (day 110)	6 l/s	36 mm

Results of simulation:

- Yield reduction: about 27%
- Soil moisture variation during the growth season: see Graph below

Supply-driven schedule: Variation of soil moisture in the root zone during the growth season



Notes:

– TAM: Total available moisture in the root zone (water hold by the soil between field capacity and wilting point)

– RAM: Readily available moisture in the root zone, which represents the moisture that can be taken up without affecting crop yield (sensitivity to increasing water stress is taken in account)

– Soil water depletion: depleted water below field capacity calculated over the root zone

– Explanation of the graph:

The 'saw tooth' line gives the variation of soil water (depletion) in the root zone of the crop during the growing season as the result of – on the one hand- the soil water withdrawn by the crop (ETc: evapotranspiration) – on the other hand- the initial soil moisture content at the time of sowing (in this case it is assumed that the whole potential root zone is at field capacity as a result of earlier rainfall), rainfall in the growing season (CROPWAT distributes the monthly rainfall in some rainfall showers evenly distributed over that month) and irrigation applications (on day 50, 70, 90 and 110). When the 'saw tooth' line falls below the RAM line, ETc and yield will be affected as a consequence of water stress (the crop experiencing increasing difficulties in withdrawing water). Rainfall or irrigation that is above the field capacity line (0-line) represents losses (deep percolation or surface runoff). Note that irrigation application losses principally occur at the start of the summer season because of, first, soil water content is still high as a consequence of former rainfall and low ETc, second, water availability (source flow) is relatively still high.

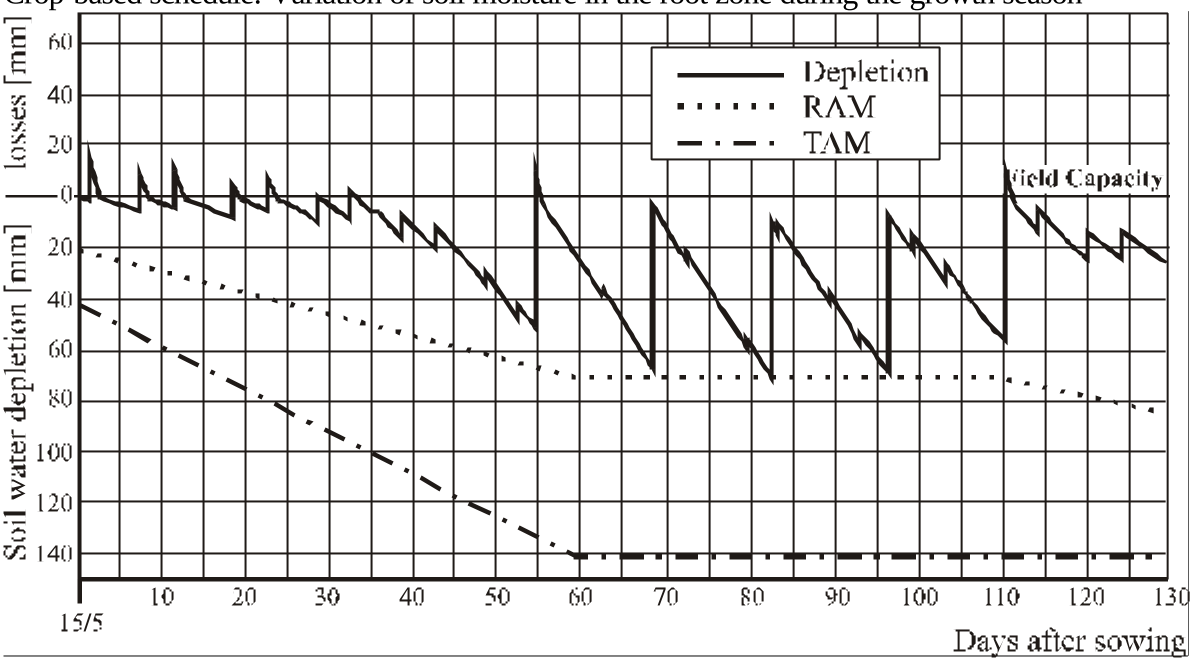
Crop-based irrigation schedule

With the crop-based or demand-based schedule, farmers themselves can decide when and how much irrigation water to apply. The crop-based schedule is aimed at maximising crop yield and minimising labour input. This implies that irrigation turns need to take place before or when readily available moisture (RAM) is depleted. It is clear that many alternatives exist: both frequent irrigations and small depths or less frequent irrigations but larger depths. When it is combined with a minimal labour input, 5 irrigation turns of 60 mm every 14 days from 9 July onwards seems a good schedule. That is illustrated in the Graph below.

Results of simulation

- No yield reduction
- Soil moisture variation during the growth season: see Graph below

Crop-based schedule: Variation of soil moisture in the root zone during the growth season



Notes:

The 60 mm depth corresponding to 72 m3/0.12 ha can be applied for instance by:

– Surface irrigation: 20 l/s *3,600 s, corresponding to an irrigation turn of 1 hour with a relatively high

flow rate (*main d'eau*) and 2 labour hours
– Sprinkler irrigation: 2 l/s *3,600s *10h, corresponding to an irrigation turn of 10 hours but with only labour input at the start and the end of the turn

The labour-intensive character of traditional irrigation practices (see Chapter 2.3) clashes sharply with the lack of labour which is the most limiting factor in the exogenous farming pattern (Ribeiro 1997; Lima Santos 1992). The simulation study of the farm models (see Appendix II) shows that, assuming that the traditional irrigation systems manage to supply the required irrigation water, high labour requirements are unavoidable. First, because of the limited streamflow and second, because of the scatteredness of many small plots (in general, a large farmer does not have larger plots but rather more small plots). Hence, it can be concluded that because of the much higher irrigation water requirements of the modern farm, and at the other hand the limited streamflows in the traditional FMIS, very much time is needed to irrigate. Because of these high labour requirements, traditional irrigation practices do not fit the modern farming styles.

In the simulation study of farm models (Appendix II), I estimate that regarding the application of the required water supply in an assumed representative traditional irrigation system with a water source that supplies a continuous average flow at plot level of 10 litres/second, a labour input of about 400 hours/summer season or 200 hours/month is required in the exogenous farm model and in the farm model representing the endogenous pattern about 140 hours/season or 70 hours/month, that is to say 1/3th of the exogenous farm model. Although these values are gross estimates (calculated on the basis of various assumptions outlined in Appendix II), it indicates clearly that if the exogenous pattern depends completely on traditional irrigation systems, the application of the required irrigation water requires much more labour compared with the endogenous farming pattern.

Hence, not only concerning the 'when' (the availability of water over the agrarian calendar) and the 'water' (the available quantity of water) but also concerning the 'labour' (the time needed to irrigate the fields and to operate the existent irrigation systems), the new farming styles clash strongly with the available resources. The endogenous farming pattern is resource based, the new exogenous farming patterns aren't any more: the resources need to be adapted to the new requirements.

The development of the exogenous farming pattern poses 5 interrelated exigencies concerning irrigation:

1 a larger quantity of irrigation water
2 an expansion of high-quality irrigable land
3 water on demand, not supply-driven
4 irrigation methods and technology that allow for a substantial decrease of labour input
5 fewer but larger plots.

The room of manoeuvre for accomodating these requirements in the traditional irrigation schemes is very limited. The possibilities for an increased supply in the existent irrigation facilities are generally constrained by natural factors. The best irrigable lands are already located within the existent traditional irrigation schemes and the needed expansion of irrigated land for fodder production can only partly be realised within the existent irrigation systems. At least, one part has to take place on arable land with poorer-quality soils without irrigation facilities. Irrigation practices (timing, frequency etc.) in the existent irrigation schemes are bound to traditional rules reflecting social agreements about the sharing of a scarce resource which often do not coincide with modernisation demands requiring a water supply corresponding to maximal crop production. It implies that irrigation on demand which assumes variable timing and variable applied water depths is hardly possible in traditional irrigation schemes. New irrigation methods (such as e.g. sprinkler irrigation) are actually being introduced but their labour saving potential is reduced because of the scatteredness and small size of plots. Much labour is required to move equipment (pumps, tubes, sprinklers) from one field to another field etc. The labour saving and large scale central pivot and raingun sprinkler technology[45] can hardly be applied in the Mountains and High Valleys because of steep slopes, small plots, the small size and variability of the water sources. On the other hand, trickle irrigation and micro-sprinklers are not compatible with the type of cultivated field crops. Finally, less but larger plots implies land consolidation which is very difficult to realise in the existing socio-economic, institutional and physical environment of Trás-os-Montes. In summary: for the development of the exogenous farming pattern it is necessary *to create a new environment*, particularly a favourable irrigation environment which clashes with the characteristics and functioning of the traditional irrigation systems.

In the foregoing it was shown that the actual irrigation practices are intimately interwoven with the structure, resources and production goals of the endogenous farming systems: the latter are essentially resource-based, irrigation practices being one of the main vehicles to do so. Thus, the role that irrigation plays cannot be isolated from the direction of agrarian development. In this sense irrigation development can be interpreted as both a condition for and an outcome of land-use intensification and increasing labour productivity, which are components of specific patterns of agricultural development.

In the discourse of the PDRITM planners, modernisation of agriculture assumes both more water and a better use of water. One of the assumptions of PDRITM was that the MRT intervention could create such conditions and in this way lay the basis for transforming traditional agriculture into a modern one. In the following chapter I will discuss in depth the question whether actual irrigation interventions are an appropriate response to the intended modernisation of agriculture.

Notes

1 There is some difference between the concepts of farming styles and farming systems. A farming style can be defined as a specific social construction within a specific ecological, socio-economic and institutional setting. This contrasts with the farming system theory which tend to isolate farming practices out of their ‘intentionality’. The definition of farming styles as social constructions implies that farmers themselves are the ones who give meaning and value to their agricultural activities. It is the

farmer which integrates the different subsystems (crops, soils, cattle, water, labour, market relations etc) into a working whole (van der Ploeg 1991:28)

2 The concept 'endogenous' is defined as 'mainly though not exclusively, founded on locally available resources' (van der Ploeg and Long 1994:1) such as the potentialities of local ecology, labour force, knowledge, local products, local networks for linking production and consumption etc. Endogenous is therefore a relational concept. It is especially useful in comparative analyses, in which more exogenous types of development, that depend heavily on external resources, are confronted and compared with more endogenous development patterns.

3 The historically created agro-pastoral system to which this chapter refers to, has its clearest expression in Barroso till about the 1940s such as is described and analysed by Lima Santos (1990 1992) and others (Pires 1970; Lema 1978). However, the main structural features of this traditional farming system have been present in other space-time contexts. For other mountainous areas of Trás-os-Montes this is described by geographers like Taborda (1932) and Ribeiro (1987). Case studies by O'Neill (1987) and Portela (1988) describe in detail similar farming systems in the *Terra Fria* ('cold land') comprising the municipalities of Vinhais and Braganca. Black (1992) does the same in a study of agricultural development in the *Alvão* mountain chain.

4 In Barroso the number of cattle increased from 11,132 in 1870 to 26,594 in 1925, an increase of 139 per cent. This increase is for nearly 100 per cent due to the increase in suckling cows (Lima Santos 1992:60, 61). In this period the function of cattle in the production process changed from mainly draught animal to principally producers of calves. These calves (5-6 months) were sold in the neigbouring region of Minho where they were fattened up and served as draught animals before going to the slaughterhouses or being exported.

5 However the climate of Barroso is very suitable to produce seed potatoes (related to the low occurrence of virus diseases). From the 1930s onwards the production of seed potatoes became very important in Barroso. It reached its peak in the years of the 2nd World War (a production of 2,740 ton of certified seed potatoes from 2,648 plots in 1944 mentioned in Lima Santos 1992:117) and declined afterwards. About 1940 the value of sold potatoes exceeded the sale of cattle for many *lavradores abastados*. This increase of seed potato production led to important changes in farming and land use. The fallow in the rye-fallow rotation was rapidly substituted by potatoes. A further expansion of the crop was on *baldios* and *lameiros*. These changes in land use corresponded to a sharp increase of labour requirements and draught force. An important effect of the need for more and stronger draught animals was the erosion and decline of the traditional Barrosã breed. Nevertheless, the Barrosã can still be found in Barroso, especially in the western part (*freguesia de Salto*). Here, farmers value this breed for its resistance against diseases, vitality and its adaptability to local ecosystems, including pasturing of the commons. It's for this reason that the Barrosã can be considered a real endogenous resource.

6 In the past, Barroso was referenced by people as the 'Portuguese Siberia' (Mendes 1980:38)

7 Poor ecological conditions are mostly mentioned as the explanation of low yields (for average yields of rye, potatoes and maize, see World Bank 1982). The cultivation of rye (instead of wheat), the most important staple crop, is an example of adaptation to the unfavourable conditions of soil and climate.

8 The word *cabaneiro* combines two meanings. One is *cavar* or to dig referring to the hard work to which this people was subjected, the other is *cabana* or hut referring to the precarious conditions in which they live.

9 During centuries the survival of the rural populations in the interior zones of Portugal was critically dependent on the cultivation of rye.

10 Up till now, in people's perception one is only a proper farmer (*lavrador*) if one has cattle and *lameiros* (Portela 1988).

11 Farmer's social status was dependent on the quantity of cattle in the farmholding which was linked directly to the farm land resources (particularly *lameiros* in quantity and quality). Households (*Casas*) with 15-20 *barrosã* cows were considered as *abastadas*.

12 Lima Santos estimated the 'carrying capacity' of 1 ha of arable land at 2.8 units of human consumption (2800 Kcal/day) and at 0.6 units/ha over the whole area in the historically created agro-pastoral system (Lima Santos 1992:91).

13 About the composition of cattle feed consumption (in terms of energy equivalents) in the agro-pastoral system, Lima e Santos (1992:85) give the following data:

- Pasture in the *baldio*: 77%
- Pasture in the *lameiros*: 5%
- Hay from the *lameiros* 13%
- Turnip and potatoe 3%
- Concentrate of rye 2%

This data shows clearly that in the agro-pastoral system cattle hardly competed for arable land resources in the production of cattle forage. The data also illustrate the dominant role of the baldio as forage resource.

14 The local breeds such as *Barrosã* (in *Barroso*), *Mirandesa* (in *Terra Fria*) and *Maronesa* (in the mountain chains of *Alvão* and *Marão*) are well adapted to the ecological conditions and serve two production goals: draught force and calves.

15 *Linhares* are tiny plots in the summer irrigation area (*veiga*). They are the most productive and accessible plots. They are the domain of the women and function as a type of store room of fresh food (Portela 1988). In former days these plots were also used for the cultivation of flax (*linho*) and this gave origine to the name *linhares*. *Nabais* literally means turnip fields.

16 To date, this is particularly valid for the 'Terra Fria'. In the 1930s a considerable part of the fallow was substituted by the cultivation of potatoes, principally in Barroso.

17 Open fields have no walls and fences, which would make pasturing difficult.

18 Lima Santos estimated the intensity of *baldio* use for pasturing at about 1.8-1.9 ha per cattle unit (*barrosã* cow) at the end of the 1930's. The productivity of the *baldio* pasture was rather elevated compared with other mountain areas in Europe. This is explained by the great number of sheep and goats which controlled the vegetation of the *baldios* (Lima Santos 1992:251, 252).

19 After the 1930s the landscape of Barroso has been considerably modified, principally by 2 factors: massive afforestation of the *baldios* and the construction of a big hydropower dam, which created a large artificial lake in the middle of Barroso.

20 In this period rye is cultivated as a rainfed crop. In April-May, vegetables, potatoes and maize are planted. From April until June these crops do not need to be irrigated, or only sporadically, because the low water requirements in this period can be met by precipitation and water stored in the soil profile.

21 The spread of maize cultivation in Alto Barroso during the 19th century was intimately linked to the increase of the irrigated area (Lima Santos 1992:64). A document written in 1813 (Alves 1813:18) expressly refers to the construction of irrigation works to expand maize cultivation. Very strangely this document also mentions (p. 19) that 'some populations of this municipality (of Montalegre) have been obliged to cultivate rice; however, these labours were not useful because neither the production was compensatory nor there was enough labour force that this crop requires'.

22 The communal irrigation systems are only one expression of the 'communitarism' in the villages and hamlets of the mountainous areas in Trás-os-Montes. Other communal resources and institutions are or were for instance the *baldios*, the collective work in the construction and maintenance of infrastructure e.g. roads, bridges, schools etc, open field arrangements combined with herding, the

communal oven (*o forno do povo*), the communal water mills and treshing floors, the collective meadows (*lamas do povo*), the cooperative work (mutual aid or *entreajuda, trabalho cooperativo*), the collective herding of cattle and small ruminants (*a vezeira*) and the village bull (*o boi do povo*). These communal institutions coexisted with a social structure characterised by smart unequality and sharp differentiation. This reflected itself also in the individual benefits derived from communal institutions. Normally all households contributed equally to the creation and maintenance of communal infrastructure but the wealthier households with most private resources benefited most of the *baldios*, road construction and maintenance etc. However, the 'communitarism' expressed in statements like *'aqui somos todos iguais'* (here we are all equal) as a ideal picture of reality is strongly sedimented in the 'collective' conscience of the communities. This paradoxal phenomenon has been the subject of much research and debate (Dias 1953; O'Neill 1987; Portela 1986; Bennema 1978; Brouwer 1995).

23 That is not to say that for an individual water user the communal system is always the only or even the most important system (see Box 2.7)

24 The population of Alto Trás-os-Montes e Douro was as its maximum in 1960. From 1864 to 1960 there was a growth of 40% in population. In 30 years until 1991 this increase was nearly nullified (Vilas Boas 1999:8).

25 The changing social relations before and after emigration is reflected in the following frequently used saying: 'before I called one worker and fifty came, now I call fifty and only one comes'.

26 For the FGLNT (Federação dos Grémios da Lavoura do Nordeste Transmontana), the traditional organisation of the large farmers in The Norte of Trás-os-Montes, the vanishing of the farming population was understood 'as a danger which is undermining the fundaments of the Nation and leading rapidly to the extinction of all agricultural activity' (*Nordeste* 1967:23 cited in Baptista 1999). In 1963, Silveirinho, a staff member of the state's regional agrarian services, made similar complaints in *O Lavrador* ('The Farmer': a newsletter on farming published in the North) made similar complaints: he stated that labour shortages resulting from emigration and employment opportunities in state-sponsored road construction works and tree planting of the *baldios* not only complicated the execution of labour intensive agrarian activities but also provoked demands for higher wages and an eight hours working day (Brouwer 1993b:10)

27 That can be illustrated with the comments of a farmer in the village of Linharelhos on the economical situation of the richest farmer (possessing 40 cows) of the village. He stated that this rich farmer nearly gained as much as an emigrant. The experience of Ribeiro (1997) in another village in Barroso points to the same direction.

28 Important in this respect was also the introduction of social security measures and the right of aged people at a (small) state pension (Ribeiro 1997).

29 SCOM: *Sala Colectiva de Ordenha Mecânica*. The collective milking parlour constitutes an ingenious solution for the problems of small dairy farmers. It resolves various problems all of a sudden. First, the problem of scale and indivisibility. At the one hand, an individual milking parlour is too big for a small farmer with 2 to 5 cows. At the same time the collection problems of the milk for the factory could be minimised. Second, the hygienic problems related with hand milking. Third, the burdensome and drudgerous nature of hand milking.

The origin of the SCOM goes back to the struggle between the *grémios* (corporative organisations controlled by the large farmers) and the cooperative movement of small farmers in the region of Beira litoral before the 'Carnation' revolution. The (State) organisation for economic coordination, closely linked to the gremios, only assigned only subsidies for milk production to farms producing more than 50 liters/day which did exclude the majority of small milk producers (Lourenço 1982). This led to a struggle resulting in the installation of the first collective milking parlours in 1971. Afterwards, this innovation spreaded rapidly all over Portugal. With the collective milking parlour the cooperatives achieved to surmount the difficulties of the dispersion of the production and the collection of the milk in areas of *minifundia*. Moreover, the quality of the milk increased.

In 1989 a total of 89 collective milking parlours functioned in Trás-os-Montes (the majority located in the High Valleys), which led to a considerable increase in the regional dairy production (Portela *et al.* 1991).

30 The use of the commons is also differentiated between villages, reflecting their scarcity or uneven quality or utilisation (Christóvão *et al.*1994:42).

31 However, this pattern is not exclusively limited to milk production. Some 'modernisers' also produce meat by more exogenous farming practices. In terms of external inputs this means pesticides, fertilisers, new cattle breeds, fattening of meat calves on the basis of milk powder, fodder crops (silo maize etc), technology and investment subsidies ('797' projects) so characteristic of the modern dairy farmers.

32 The production of hay as an important winter fodder resource is the main limiting factor for the quantity of meat cattle a farm can hold.

33 The exogenous pattern not only reflects but also results in the marginalisation of the commons as a fodder resource. The commons have been maintained and improved by regular pasturing of cattle and small ruminants over the centuries. Without pasturing, the dominant vegetation of these heathery areas, on shallow soils with mostly grasses and ferns in the more humid parts, would gradually turn in shrub vegetation, unsuitable as a fodder source. It is only through continued and well-balanced use that the commons are reproduced over time as a valuable local resource. Once active use diminishes, both real and potential value decline (Christóvão *et al.* 1994).

34 To produce more winter fodder the extension and intensification of *lameiros* for hay is another option. In fact, 'good' *lameiros* are procured by all cattle farmers at a high rent. The concept of 'good' *lameiros* comprises both productivity and increasingly a minimisation of the labour input in *lameiro* exploitation. Criteria such as access, size, slope, drainage conditions and conditions for mechanisation of hay preparation and harvesting are gaining increasing importance (see Box 2.6). A research project dealing with the production and use of *lameiros* (Ferreira *et al.* 1990) mentions fertilisation and treatment with lime as measures to increase the production of *lameiros* and chemical treatment with urea as a measure to improve the quality of hay. The irrigation of *lameiros* in the summer period has recently increased but under water scarcity conditions it implies a decrease in cultivation of summer food crops (potato, maize). This tendency can be explained because in most households less food crops are necessary for self-sufficiency and farm gate prices are too low to produce profitably excedents of this crops.

35 These fodder crops, principally the silage maize (hybrid varieties) tend to increase in importance and acreage. These crops need good-quality arable land and relatively abundant irrigation water (Rego *et al.* 1990). The cultivation of these fodder crops is associated with a series of technological changes and inputs such as the abolishing of the intercropping with beans, hybrid seed, herbicides, chemical fertiliser and correction of soil acidity by limestone. Normally these crops are cultivated on arable fields that allow for a more easy mechanised cultivation and harvest operations than *lameiros*. A higher labour productivity can be realised by the combined effect of higher yields and less required labour time per area.

36 These farmers are all farmers with livestock production. They constitute a group for which farming still has a development perspective and who intend to continue in farming. Therefore they are not representative of the 'average' farmer in the region. The average farm size in this group is about double the regional average, 15.1 and 7.0 ha respectively (Oostindie *et al.* 1993)

37 The analysis of the accountancy data yielded a total of 4 farming development patterns: one exogenous ('modernisers') and 3 more endogenous patterns including the 'intensifiers' (Oostindie *et al.*

1993). In the sample of 39 farmers, 6 displayed outspoken characteristics of the 'modernisers' category and 12 of the 'intensifiers' category.

38 The purchased concentrate can be considered to represent an additional quantity of imported, 'virtual' irrigation water when the concentrate or part of it is produced under irrigated conditions. Thus, from a macro perspective, the exogenous pattern still makes more demands on irrigation water than it seems at first sight.

39 The difference between irrigation water requirements and actual irrigation water used (under-irrigation) can be translated in yield losses. This will differ between the farms.

40 The modern pattern has a considerable share (40% of SAU summer irrigation) of 'modern' fodder crops as silo maize and temporary meadows.

41 The dominant summer forage crops (green forage maize and parts of the potato and maize harvest) in the traditional farming pattern are less dependent on an abundant water supply. A traditional farming characteristic in Trás-os-Montes is the adjustment of agronomic practices to water scarcity. The second inventory study (Malta *et al.* 1993) yielded very interesting data concerning these practices (see also Chapter 2.5). The 'modern' crops (and varieties) as silage maize (hybrids) are much more demanding and rigid concerning ecological conditions and water supply than traditional crops and varieties (regional maize).

42 The farm accountancy data are limited because only the data of 39 farmers during one year (1989) were available. So, the results also reflect the specific conditions (climatic conditions, prices etc) of that year.

43 Examples are the installation of individual wells and tubewells which affect the water availability of traditional sources, the decline and the collapse of communal systems as is documented in the inventory studies (Bleumink *et al.* 1992:25; Malta *et al.* 1993:56). In other documents is referred to these processes in the villages of Cimo de Vila de Castanheiro, Vilar de Lombo (Malta 1992), Adães (Morgado 1992:13,15).

44 However, until recently the dimension of the exogenous farm development pattern was really limited in the socio-economic and ecological reality of Barroso. In 1989, the number of these farm households did not exceed 50, out of a total of 4625 farm households in Barroso (INE 1991).

45. These technologies are advancing in the Alentejo and Ribatejo e Oeste. From 1986 until 1996, IFADAP financed the installation of 679 central pivots with a capacity to irrigate 19,600 ha. It supported also the acquisition of other sprinkler systems covering an area of 52,000 ha. In the last years trickle irrigation is also expanding. The great majority of these new systems were installed in new areas (Sousa 1998). The introduction of these technologies is heavily subsidised and directed at large farmers. However, in many cases these technologies are used less efficiently in comparison with traditional methods (Pires 1999)

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6 Public Irrigation Interventions in Trás-os-Montes

In this chapter I will present a critical analysis of the public irrigation interventions in Trás-os-Montes. I will focus on the MRT intervention, its underlying assumptions and its impact.

In Chapter 5 it was shown that 'modernisation' contains a tendency towards counter-productivity where water as a scarce resource is concerned, although theoretically this might be remedied by a strong decrease in water losses and/or by an increase in water use efficiency. Whether this is the case will be explored in this chapter.

'Modern' farming styles require more water than 'traditional' styles, particularly scarce water in the summer for increased fodder production, other irrigation practices and a different functioning of irrigation systems. These requirements coincide with the PDRITM philosophy, which considered more water in the summer and as 'better' use of water a basic condition for modernisation, i.e. the transformation of traditional agriculture in intensive and competitive animal husbandry (see Chapter 4). To create favourable conditions for the modernisation of agriculture in Trás-os-Montes, irrigation interventions have been designed and implemented in the framework of the PDRITM programme and later on in the PEDAP programme which is conceptionally a continuation of the PDRITM. The interventions aimed particularly at increasing considerably the availability of irrigation water through the limitation of water losses. In this chapter I will discuss the question if and to what extent these interventions, particularly the MRT intervention have succeeded in creating these conditions. To this end, the intended results of the MRT intervention, especially the expected increase of available irrigation water will be analysed. I will compare intended results with real outcomes and examine the underlying assumptions of the technicians who designed the PDRITM programme upon which the MRT intervention is based.

Another relevant question is the impact of the MRT intervention in relation to agrarian development. Therefore, the effects of the MRT intervention in the field will be evaluated. Regarding these effects, the implications of the MRT intervention for the farming style of the 'modernisers', described in Chapter 5, will be analysed.

A basic assumption underlying modernisation programmes is that traditional agriculture has reached its technical ceiling[1] (Schultz 1964). In an agricultural sector report of the World Bank (1978) this assumption is reflected in the statement: 'These schemes are fully utilised within the limits of their generally unimproved water supply'. Therefore, development requires external intervention and new technologies are to be introduced. That was also the point of departure for the PDRITM and the justification of its irrigation interventions. This is, for instance, reflected in the statements that 'we know that the majority of the traditional irrigation systems are imperfect but it is also true that the

State finally acknowledged that the rural populations only by themselves with traditional means could have achieved not much more' (DGRAH 1987) and 'The traditional irrigation systems which have been constructed by the rural communities, without any technical support, are necessarily imperfect' (Rego *et al.* 1988; 1990). These ideas about 'traditional' agriculture and irrigation practices are echoed again and again in policy, academic and technical circles and finally seem so obvious that empirical analysis is deemed unnecessary.

Apart from the fact that 'perfect' irrigation systems do not exist, this focus on 'technical' imperfectness indicates a very narrow perception of irrigation. It is impossible to separate physical capital (infrastructure), social capital (rules) and the human capital (skills) involved in the functioning of irrigation systems. A 'high-tech' irrigation system could function highly suboptimally when rules and skills are not mutually adjusted to this technology. In the same way a 'low-tech' irrigation system in combination with appropriate rules and skills could achieve a remarkable efficiency in attaining the objectives for which they have been created.

In my opinion *public intervention* will constitute a rupture with space and time specific practices and dynamics if it is not linked to specific local needs, context and resource management. Public interventions world-wide have tended to neglect local complexity and diversity and have tried to change or replace local conditions, traditions and practices in function of the (technological) exigencies inherent to an uniform external development model, instead of supporting locally-driven development and adapting technology to the specific situation.

The character of the MRT intervention is not the same as the classic intervention described above. In the conception of the technicians, MRT was a purely technical intervention. But the MRT intervention has an ambiguous character. On the one hand the skill-oriented nature of irrigation practice is acknowledged, but as a '*fait accompli*', it is perceived as an obstacle to modernisation, but one that hardly can be moved away[2]. This ambiguity I have encountered again and again in publications by government agencies, academia and consultants related to agrarian development and irrigation practices. The disembodied and 'dehistorised' description and analysis of real or supposed problems in these publications is remarkable: no word about existing irrigation practices, the why and how of these farmers practices in Trás-os-Montes, this 'rudimentary' irrigation simply seems the result of an 'intrinsic' backwardness and not the product of an historical process of careful mutual adaptation of the 'social' and the 'material'. In Box 6.1, I give some examples of this type of analysis.

Also the diversity and complexity of the irrigation systems are considered matters of fact in the sense that they constitute obstacles that cannot be moved away and not as something to build upon in (re)designing the systems. It was a principle of intervention not to interfere in local customs, rules, practices and habits because this was considered too difficult and too conflictive[3]. At the other hand the technicians involved in the MRT intervention assumed that the potential of many existing systems was not realised because of faulty management (Gusmão *et al.* 1987). So it is clear that the MRT intervention did not build upon the skill-oriented irrigation practice and was not considered the point of departure for the improvement of the systems. On the contrary, farmers' irrigation practices were considered a complication hindering the full realisation of project objectives.

For most farmers the MRT intervention generated positive but limited and heterogenous results. The lining of canals, the main activity of the MRT intervention, fitted well into the initiatives already undertaken by the farming communities themselves. In that sense the MRT intervention principally meant a cheap upgrading of their systems used in Summer and a partial adaptation to labour shortages.

In the following two sections I will analyse the underlying assumptions of the MRT intervention and the impact generated by the MRT interventions respectively. In Section 6.1 the underlying assumptions upon which the MRT intervention is based will be compared with the real situation, particularly the idea that the MRT will yield a considerable quantity of incremental irrigation water through the limitation of water losses. Section 6.2 will consider how the standard MRT intervention works out in a heterogeneous environment, principally its effects in the field will be evaluated and its implications for the development possibilities of the different farming styles.

6.1 Underlying assumptions of the MRT intervention

In the formulation of the PDRITM programme and its MRT component the functioning and potential of the irrigation systems before intervention were wrongly assessed. The functioning of the irrigation systems, its complexity and diversity have been misunderstood and neglected. The physical potential of the irrigation systems, i.e. the water availability of their water sources in the summer, has been grossly overestimated as will be shown below.

The basic idea behind the MRT programme was that by reducing water losses through lining irrigation channels, a lot of incremental water would become available, which would permit a substantial increase of irrigated area and consequently of irrigated crop production. The incremental water was to be used on former rainfed land, principally to irrigate temporary meadows at about 50 per cent of the rainfed farm acreage (see Chapter 4 and 5).

The MRT programme was based on the following underlying assumptions. First, that in the traditional irrigation systems quite a lot of water was available (Vilhena de Gusmão 1985:181; Gusmão *et al.* 1987). Technicians involved in the MRT programme supposed an average size of about 50 ha for a typical traditional irrigation system. Canal discharges have been supposed to be in the range of 30-60 l/s (Gusmão *et al.* 1987). Secondly, that the efficiency of these systems is very low because of their rudimentary hydraulic infrastructure. They assumed that the water losses could be reduced from 50 per cent to 20 per cent of the original source flow, thereby increasing about 60 per cent the amount of water available in the summer period which will be mainly used to irrigate meadows and other fodder crops.

Box 6.1 Examples of Ambiguity in relation to agrarian development and irrigation practices in Trás-os-Montes

A telling example is a report by DRATM *et al.* (1984) full of contradictory statements but a perfect echo of what can be read in many other documents. First it is stated that ‘the irrigated areas are very limited in relation to the hydrological potential’ (p.13) and ‘one of the principal objectives (of PDRITM) is the technological development of agriculture, principally of the smallholdings, through the substantial increase of irrigated areas’ (p. 21). But on the same page the authors write: ‘at the same time one of the principal bottlenecks in the region is exactly the lack of water in the summer months’ (p. 21) and ‘at the same time the availability of water is not sufficient in the sense that the introduction of irrigated crops produces the desired agronomic and economic effects’ (p. 23). It seems that the authors do not know the crucial importance of irrigated *lameiros* in the existent farming systems when they write: ‘The cattle production (.......) is not integrated in the farm cultivated area because the cattle fundamentally live on the production of the *lameiros*’ (p.76). It is exactly the irrigation of *lameiros* that constitutes the most important irrigation practice representing 2/3 of the total irrigated area in the mountains. Sometimes it seems that they just discovered virgin land without people and their history, tradition and knowledge, at least nothing of any value. In this respect it is remarkable the neglect or ignorance of farmers’ experience in irrigation as they write: ‘It will be convenient to have specialists (...…..) to teach the farmers in irrigation techniques, directly after the water is available in the fields’ (p. 23) and ‘the expected modifications in the farms through the introduction of a new production factor- water- which will result in substantial changes in the farms’ (p. 96). But that water would be a new production factor is contradicted by another statement that ‘the small irrigated areas (of farms) are maintained by deficient traditional irrigation systems’ (p. 24). From these statements it becomes clear that the authors consider the existent irrigation practices of farmers of no value and have to be replaced by new methods that they need to be taught. They consider that a complete change is necessary in the agricultural sector as shows the following statement: ‘Finally, we (the consultants, AvdD) have the opinion that after a ‘conservative’ transformation (.........) it will be possible in the future to make more innovative proposals in relation to Trás-os-Montes, at that time integrated in the EEC, and where its development is incompatible with the maintaining of a primary sector with 70 per cent of the total active labour force’ (p. 96). From that, it appears they fail to understand the functioning of actual farming systems, which are characterised by pluriactive livelihood strategies of the farmers. Moreover they do not make it clear how an intensification of agriculture and cattle breeding by means of new irrigated crops (vegetables, fruits, fodder crops) will be possible, taking in account the actual scarcity of labour.

The ambiguity regarding farmers’ irrigation practices is clearly reflected in the Portuguese professional irrigation literature. This ambiguity can be summarised thus: ‘the actual irrigation practices reflect and are adjusted to our conditions but they are not modern’. For instance, in an extension paper for farmers, published by the Ministry of Agriculture, Fisheries and Alimentation (Raposo 1989) and in a recent published irrigation handbook, prof. Raposo (1996) praises the irrigation method of contour ditch irrigation (*rega de lima*) used to irrigate *lameiros*. As advantages are mentioned its use on steep lands (sometimes with slopes steeper than 30 per cent) and thin soils covered with meadows, which counters erosion (p.283). Because there is hardly need to level the land, the cost of investment is very low, which is why this method is very economic (p. 284). He states that ‘this irrigation method is the only possible within the gravity irrigation systems to be used beneficially on steep lands where levelling is not viable for technical or economic reasons'(p. 289). But then, on the same page he states that 'in modern agriculture this irrigation method must be avoided because it's hindering mechanisation of crop husbandry operations and it has a low irrigation efficiency (water losses and a low uniformity of field application).' A contrary opinion is provided by prof. Azevedo (1999) who states that this technique is perfectly suitable to be modernised, but he did not elaborate on it.

It must be noted that the low irrigation efficiency of *lameiro* irrigation is hardly relevant because of the abundance of water in winter and spring. Moreover there is no other alternative, profitable use of water possible in that period. It can even be defended that *lameiro* irrigation is a sound practice exactly because of its low efficiency. 'Losses' represent storage of water in the soil profile and recharge of groundwater which otherwise would have been useless runoff.

Another example of the fixation on 'modernisation' is the UTAD research project called 'evaluation and improvement of traditional irrigation methods', financed by PDRITM. In the reports (Rego *et al.* 1988; 1990) the researchers first state that 'the traditional irrigation systems, made by the populations without any technical support, are necessarily imperfect' (1988:2; 1990:1) and ' it is needed to make certain corrections which minimise within the possible the errors practised until now' (1990:3). However when it comes to an empirical evaluation of the practised traditional field irrigation methods ('*embelga*' and short closed furrows, see Chapter 2.3) they conclude that 'the choice of these irrigation methods is made with good judgement taken into account the topography of the fields and the physical characteristics of the soils' (1988:10) and 'in the terraced mountain fields it seems to us difficult to improve the used method of surface irrigation (*embelga*)' (1988:22). They mention also that 'the use of long furrows, so much used in other countries with automatised irrigation, here seldom can be employed due to the small size of the plots, the limited available irrigation flows and the high costs of levelling' (1990:3), that 'levelling is limited by the small depth of the rootzone of the soils' (1990:47) and that 'the implantation of new surface irrigation methods which make possible the use of more advanced technologies need fundamental changes implying levelling, an increased storage capacity to enable major and more constant field flows and more adequate irrigation units' (1990:48). With regret they conclude that 'taking into account the conditions of the existing irrigation systems, the small irrigated plots, irregular topography and small, variable field flows, it is not possible to think in advanced processes of distribution and control already much used in other countries like cablegation, and surge flow' (1990:49). Finally, they propose a solution to reduce labour input in field irrigation, namely the use of siphons in order to irrigate more furrows instead of irrigating one furrow at the time. With the use of siphons, they claim, a reduction of about 80 per cent in irrigation labour input per ha was achieved (1990:53) but this effect is not elaborated further. I think that indeed siphons can have a labour-saving potential but only in specific conditions like long furrows, regular topography, relative large and constant field flows, relatively long irrigation times which are adapted to the infiltration characteristics of the soils etc. In this way a farmer, after installing the siphons, can do other things and return to his field when irrigation time is about to finish. But I think that this claim is not valid for Trás-os Montes conditions (small plots, irregular topography, small and variable field flows) is not valid because the time that water is available for a field, the farmer has to be there to control the irrigation directly (all kinds of problems related to these conditions can occur) no matter if he is putting the whole field flow in one furrow or divide the flow over e.g. ten furrows by means of siphons. Moreover, the correct use of siphons implies special technical conditions (equal furrow flows, hence equal head losses, equal furrow lengths, a constant field inflow which is incompatible with variable reservoir outflows) which

are difficult to realise.

Third, it was stated that the irrigation water is not used productively. Gusmão *et al.* (1987) mention 'deficient use of the water', 'deficiencies in management and utilisation of the hydraulic infrastructure' and that 'faulty management is a factor seriously affecting potential production levels' but these statements are not further elaborated. In the document containing the results of the inventory of the FMIS in Trás-os-Montes (DGEA *et al.* 1980) the irrigation systems are characterised as incipient systems which only 'wet' (*molhar*) the land. Typical is that the most important irrigation practice, namely the irrigation of hay *lameiros* which represented 2/3 of the total irrigated area in the mountains (see Table 2.3), is hardly mentioned or acknowledged as being the only practice which makes the water in autumn, winter and spring productive[4].

All these underlying assumptions proved incorrect as will be shown by empirical evidence.

Overestimation of available water

In Summer 1992 and Summer 1993 a group of irrigation researchers, based at UTAD-DES executed a series of discharge measurements at source level. Results of these measurements in August 1992 showed that from a sample of 28 communal systems 19 had a source flow of less than 1 l/s and only five had a flow in the range of 5-25 l/s (See Table 2.6). Discharge measurements in August 1993 (1993 was a relatively wet year compared to 1992) showed that in a sample of 12 communal systems, 2 had a source flow in the range of 10-15 l/s, 1 in the range of 5-10 l/s, 3 in the range of 2-5 l/s and 6 in the range of 0-2 l/s.

Thus, it is clear that PDRITM, assuming canal discharges in the systems in the range of 30-60 l/s, grossly overestimated water availability in the systems. That signifies that already on the level of basic assumptions the expected benefits from MRT, especially the possible increases in available water, irrigated land resources and consequently, irrigated fodder were also grossly overestimated.[5] In order to explain this, let us assume that the initial water availability in the summer at field level is equal to 100 units. If this real value has been overestimated by, for instance, 100 per cent then the overestimated initial water availability at field level is 200 units. Assume that the increase of water availability as result of the MRT intervention is equal to 60 per cent, as PDRITM does. Then the real water availability at field level after intervention is equal to 100 + 0.6*100=160 units and the overestimated water availability at field level after intervention is 200 + 0.6*200=320 units. According to the PDRITM assumptions, it can be concluded that the effect of the MRT intervention – the summer water availability after intervention (320 units)- is overestimated by 100 per cent of the real water availability after intervention (160 units) and by 220 per cent of the real initial water availability (100 units).

Consequences for irrigation design

Another assumption was that the extra summer water would be used to increase irrigated areas and/or to irrigate (temporary) meadows. First, for many farmers these objectives are not relevant. Second, it was not realised that some allocation principles, for instance the plot-based allocation principle, restrict water use (see Table 2.7).

The overestimation of water availability, irrigated areas and envisaged changes in cropping patterns are also reflected in the *design of the improved systems*. First, the technical design i.e. the dimensioning of canals and reservoirs, is uniquely based on the summer water requirements of a supposed irrigated area (which is frequently overestimated) with an idealised cropping pattern containing a high portion of temporary meadows, which reflects a clear focus on the cropping patterns and water demands of the exogenous farming patterns. In Chapter 4 it was already mentioned that the assumed cropping pattern in the design of the rehabilitated irrigation systems fully coincides with the envisaged cropping patterns in the new farm models proposed by PDRITM. However, the available water supply is completely overlooked or it is assumed not to be a constraint. Second, channel lining to reduce water losses is the dominant technical measure and is assumed to be the measure that results in the largest impact. Normally the upstream reaches of the main irrigation channel(s) are lined continuously (not selectively) without considering the actual losses in these parts or in other parts of the channel system. Third, actual farmers' irrigation practices have been overlooked. In some villages, irrigation channels have been designed for summer irrigation only without considering the use made of these channels in the winter period as reflected in the following comments of farmers (Rocha e Silva 1988):

> *'The winter water (água de lima) does not fit the canal, before 5 or 6 people irrigated at the same moment, now the water is only enough for one'* (irrigator Sezelhe)
>
> *'Yet I said to the engineer that that canal was too narrow'* (irrigator Vidoedo)
>
> *'The users know better than anybody how the water is conducted and distributed'* (irrigator Arrabães).

From a sample of 53 improved irrigation systems, 8 have reduced canals (Portela 1990a) which hindered the irrigation of *lameiros*.[6] In some cases *lameiro* plots changed to cereal production. In other cases channels have been positioned too high or substituted by tubes hindering the 'dirty' manure-loaded surface water, much appreciated by farmers, to flow in and to be transported to the *lameiros*.

In four MRT designs (DRATM 1981; GAT 1985; Guerra 1987; Fonseca Calvão 1990) I had access to, the water requirements and canal dimensions were invariably based on the same cropping pattern: 50 per cent temporary meadows, 25 per cent potatoes and 25 per cent rye. In the designs no reference was made to the available water supply of the systems. The improvement of the communal irrigation system of Sesmil is a striking, although a somewhat extreme, example of the standard MRT design based on these assumptions. It shows clearly that the real local situation was completely neglected. This resulted in irrigation facilities with monstruous dimensions and properties as is shown in Box 6.2.

Box 6.2 MRT design of the communal irrigation system of Sesmil

In the designed improvement, canals were lined and a new storage reservoir -replacing the original one- was constructed on the basis of a discharge in the summer of 50 l/s. This discharge is based on the irrigation requirements of an area of 55 ha supposing an idealised cropping pattern with 50 per cent temporary meadows. In reality, the discharge in summer is always lower than 1 l/s (in July 1992 the measured flow was 0.4 l/s), irrigated area in summer does not go beyond 5 ha and in Sesmil livestock production is not at all a priority for the local farmers. Moreover an important part of the area is irrigated by means of private wells.

Regarding the supposed design discharge of 50 l/s there is no reason for a reservoir because this discharge can be used to irrigate directly. On the other hand, the new reservoir with a capacity of approximately 200 m3 (Pinto Marques 1994) is too small for the assumed 50 l/s. It can only contain one hour of discharge when average time shares are 5.5 hours.

But considering real flows the reservoir turned out to be extremely overdimensioned. The reservoir cannot even function as a swimming pool. With some exaggeration this reservoir can be characterised as an enormous evaporation pan. Moreover, because of the very small water depths in the reservoir, corresponding to average actual time shares, farmers complain that water is not forced to flow out with an adequate discharge that can be used directly for field irrigation (Pinto Marques 1994). To overcome this problem the farmers transport their water from the new reservoir to a former reservoir which was already functioning before the improvement. This is a much smaller reservoir (47 m3) in which water can gain head and reasonable field discharges can be achieved. The combination of the two reservoirs function as a double reservoir. It can be concluded that the new overdimensioned reservoir does not bear any relation to real irrigation practices. As such it is a superfluous investment and a waste of resources.

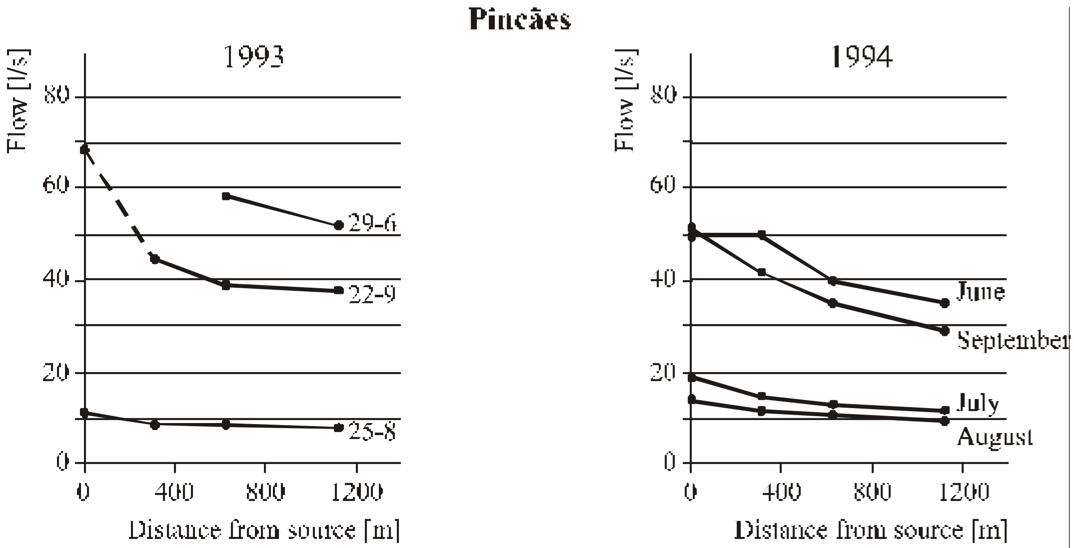
Reduction of water losses

The second assumption that the water losses will be reduced from 50 per cent to 20 per cent by canal lining, increasing by about 60 per cent the amounts of water available in the summer period is also contradicted by empirical evidence. In the Spring of 1993, I assisted in the set-up of a discharge measurement programme in 12 unimproved traditional irrigation systems. These irrigation systems were selected from a list –supplied by the DSEA- of irrigation systems which had been planned to be improved after 1993. The criteria to select the systems for discharge measurements have been the location (in the High Valleys or Mountains) and a continuous flow in the main channel (to avoid measurements of variable reservoir outflows).

The programme has been executed during the Summer months of 1993 and 1994 by research assistants from the UTAD-DES-based Evaluation Unit (*Unidade de Avaliação*) of the PDRITM programme. To make an assessment of occurring channel losses, discharges at specific points along the main channel points in each irrigation system have been measured[7] during the summer months.

The outcomes of the measurement programme (Pinto Marques *et al.* 1994; 1995) showed that, first, source flows are lower in High Valley systems than in Mountain systems, as was to be expected. Second, in the two summer irrigation periods the rainfall and the available water flow for irrigation have been highly variable. In 1994 more irrigation water was available in the summer period than in 1993, summer irrigation started later (1993: in June; 1994: in July) and ended earlier (1994: August; 1993: September), thus more water during more time was available for *lameiro* irrigation. Exceptionally, *lameiros* have been irrigated in the village of Viveiros during the whole summer period of 1994. Third, the measurements gave very heterogenous outcomes. This will be illustrated by the following four examples, all situated within the municipality of Montalegre (Barroso).

Figure 6.1 Traditional irrigation system of Pincães
Discharges in the main channel in Summer 1993 and Summer 1994



Station 03L/08 Pincães (precipitation [mm])												
Rainfall	O	N	D	J	F	M	A	M	J	J	A	S
1992 - 1993	131	62	153	38	5	39	150	171	57	1	8	144
1993 - 1994	446	188	146	406	292	17	100	354	31	14	73	135

Source: INAG (1997)

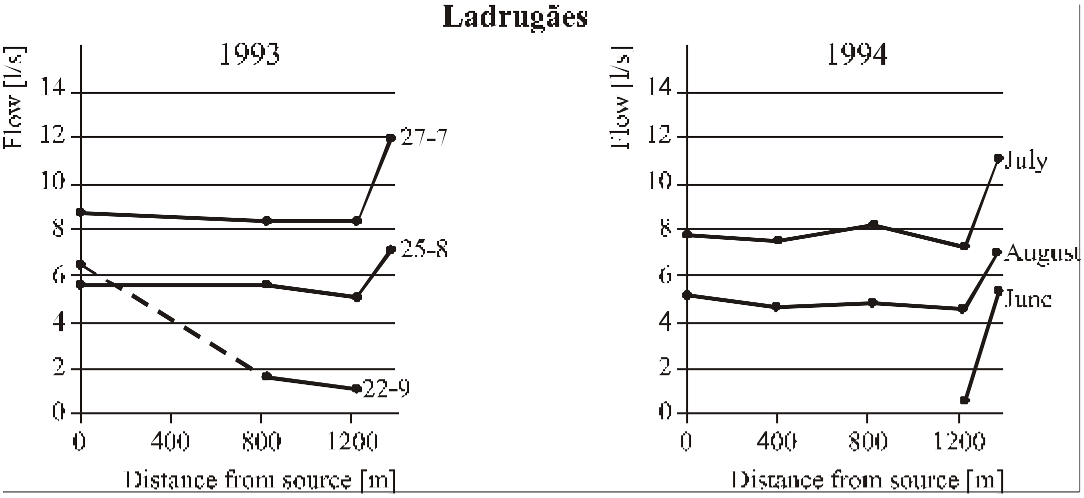
Notes:

- The dashed line referring to September 1993 does not indicate a channel loss. A big part of the available water (70 l/s) at point 1 (the beginning of the channel) was returned to the brook because the water demand in the area was lower than the available supply. Also the measurements of September 1994 are not representing canal losses because part of the canal flow was diverted to the *lameiros* next to the canal.
- In 1993, August was the critical month concerning the water supply. Some farmers hardly received any irrigation water. This can be explained not only by the low water availability in August but also by the established water rights and how the local water distribution is organised. Farmers are organised in distribution groups (*casais*). Each distribution group receives water for one day in a

period of 5 days. Within the distribution group water goes from plot to plot in a fixed sequence (plot-based). Because water supply in August was low, the farmers with the plots that are the last to irrigate in that group remained without water. They had to wait the next turn(s) for water to irrigate their plots (see Chapter 2.4). In July and August 1994 the situation was different, there was more rain in these months than in 1993 and farmers could irrigate their crops with a relative abundance because canal flows were higher than in 1993.

– Average water losses between points 1 and 4 in August 1993:4 l/s or (4/11)*100=36 per cent; in August 1994:4.5 l/s or (4.5/13.9)*100= 32 per cent.

Figure 6.2 Traditional irrigation system of Ladrugães (System of Portafoz)
Discharges in the main channel in Summer 1993 and Summer 1994



Notes:

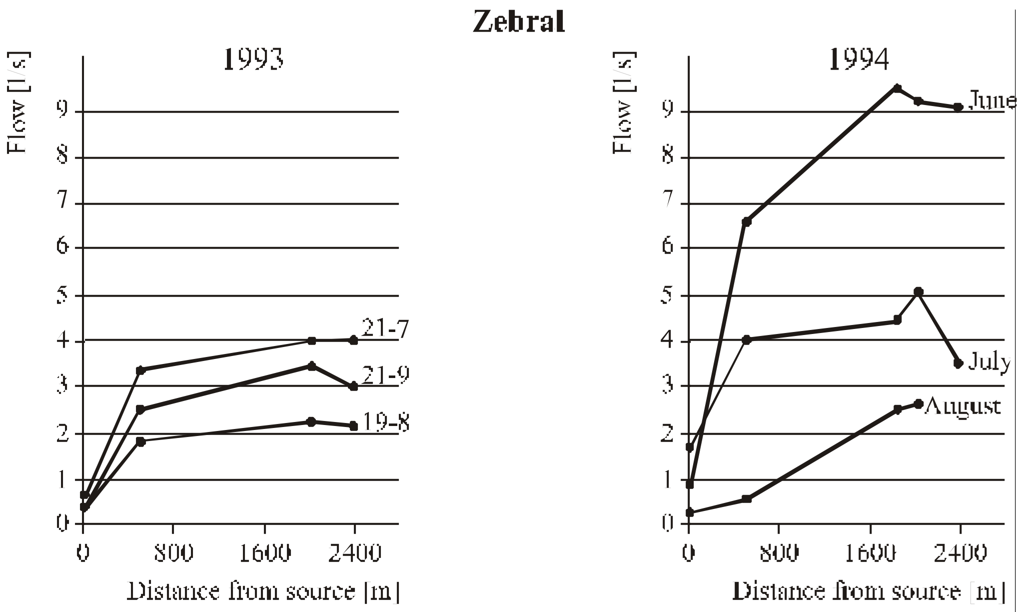
– The dashed line referring to September 1993 does not indicate a channel loss. Because of intense rain in the month of September and consequently a low water demand in the *veiga* (summer irrigation area), part of the water have been used for the irrigation of the *lameiros* between points 1 and 2.

– Between points 3 and 4 not a loss but a gain in water was measured. This is due to the existence of various springs in this zone. A local rule states that in the summer months these springs, however located on private lands, must be channelled to the communal irrigation system of the veiga. It is expressly forbidden to use these springs for irrigating nearby meadows. This type of rules are found in many Barroso systems.

– In June 1994, most water between points 1 and 3 was used for the irrigation of *lameiros* in this area. In September all water was used for the *lameiros* in this area.

– Average water gains between points 1 and 4 in August 1993: 1.8 l/s or (1.8/5.5)*100=33 per cent; In August 1994: 1.6 l/s or (1.6/5.2)*100= 31 per cent

Figure 6.3 Traditional irrigation system of Zebral
Discharges in the main channel in Summer 1993 Summer 1994



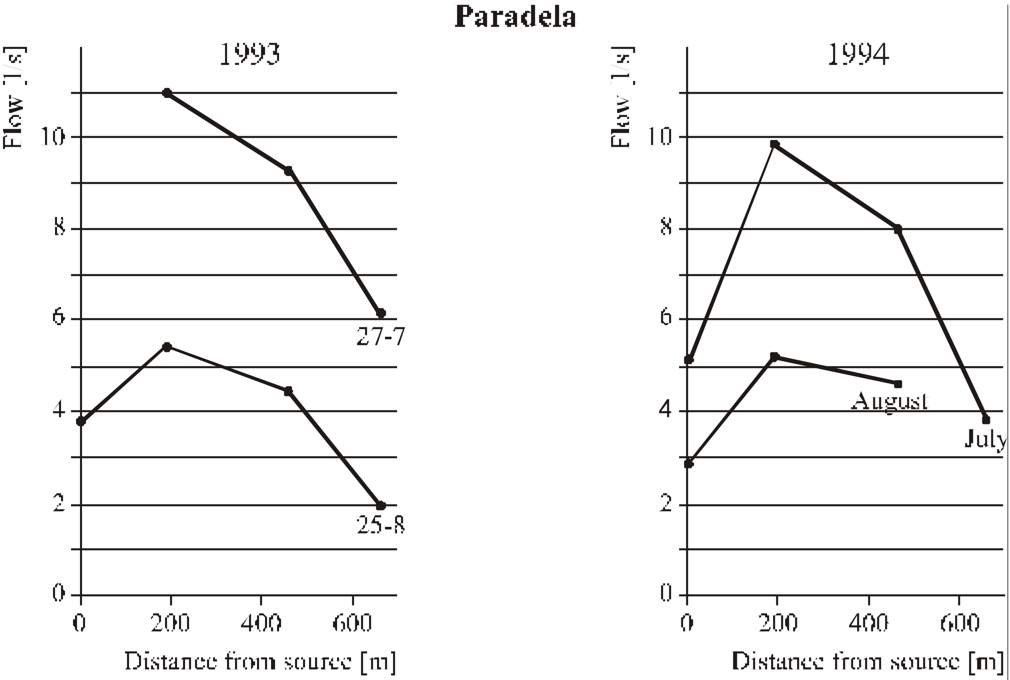
Station 041/03 Zebral (precipitation [mm])												
Rainfall	O	N	D	J	F	M	A	M	J	J	A	S
1992 - 1993	199	151	437	188	13	54	287	403	69	2	15	304
1993 - 1994	623	289	119	610	408	13	154	487	30	8	80	113

Source: INAG (1997)

Notes:

- Along 80 per cent of the main channel not a loss but a gain in water is measured. This is due to the existence of many small springs (mostly hardly visible) in the *lameiros* next to the channel between points 1 and 3. This channel functions also as collector of excess water of *lameiro* irrigation. Channel losses are only measured between points 3 and 4.
- In 1994 *lameiro* irrigation started already in September so the canal was not in use.
- Water gains between points 1 and 4 in August 1993: 1.9 l/s or (1.9/0.4)*100=475 per cent; August 1994: 2.4 l/s or (2.4/0.3)*100= 800 per cent between point 1 and 3.

Figure 6.4 Traditional irrigation system of Paradela
Discharges in the main channel in Summer 1993 and Summer 1994



Station 03J/03 Paradela do Rio (precipitation [mm])												
Rainfall	O	N	D	J	F	M	A	M	J	J	A	S
1992 - 1993	74	33	165	62	3	18	136	132	65	0	21	122
1993 - 1994	397	240	84	415	303	18	87	349	19	20	52	98

Source: INAG (1997)

Notes:

- Between points 1 and 2 not a loss but a gain in water is measured. This is due to the existence of springs in a zone of *lameiros*. Channel losses are measured between points 2 and 4.
- The water in the canal in June and September of both years has been used for the irrigation of *lameiros*. There was no necessity to irrigate in these months summer crops.
- Between points 2 and 3 about 85 m have been lined not only to reduce water losses but also to avoid the erosion of the canal caused by high water velocity.
- Water losses between points 1 and 4 in August 1993: 1.8 l/s or (1.8/3.8)*100=47 per cent; July 1994: 1.2 l/s or (1.2/5.1)*100= 24 per cent

From these examples it becomes clear that the assumption that water losses will be reduced by the MRT intervention is not generally valid. The rate of channel losses is very different from the assumed 50 per cent and far from uniform. The reduction in losses from 50 per cent to 20 per cent, increasing by about 60 per cent the amounts of available water, proved to be a pure guess. A very heterogenous picture emerges in which the assumption of the occurrence of water losses in no way is an uniform phenomenon but strongly dependent on local hydrological conditions, other natural factors but also on working rules (such as the rule that during summer months all springs in the *lameiros* must be channeled to the *rego do povo*). In some irrigation systems, even gains of water have been measured in the direction of the flow!

Effects of lining

In the discussion about the efficiency of these systems, I will now consider a crucial question. That is: what exactly is a water loss, how to look at water losses in irrigation systems, are they real losses? In many irrigation interventions across the globe these questions have not been posed. Water losses in channels are considered isolated from the hydrologic cycle and the environment in which irrigation systems function. From this narrow perspective water losses represent inefficiency. In a broader view, water losses are not real losses in many cases but constitute the source for other uses, for instance return flows to surface water and/or groundwater aquifers that are used further downstream by other irrigation systems. In such cases lining does not appear as a remedy to eliminate an inefficiency but as an intervention with opposite effects. Lining affects the interests of other users and has only redistributive effects. These savings (as a consequence of lining) are 'dry' or 'paper' savings and not 'wet' or 'real' savings[8], to paraphrase Seckler (1996).

Also in Trás-os-Montes systems it can often be questioned whether channel losses indeed represent real water losses considered in a broader context (Prins 1991). The hydrological situation in many villages is characterised by the occurrence of many small dispersed water sources that are interdependent. A water loss from one source may very well be a gain for another water source. In the same way, water that infiltrates from an earthen channel may reappear as the yield of a downstream spring or as seepage water in a meadow.

Lining might decrease total system losses (the system considered as an isolated entity) but farmers who took advantage of these losses often do not agree with such improvements. They had unofficial but clear, local accepted rights on leakage water.

For instance, in some communal systems which have seen intervention, herdsmen destroyed a part of the lined channel exactly because their meadows dried out whilst before intervention the meadows stayed green because of seepage water[9] (Rocha e Silva 1988). A similar case is that before lining, plots in the beginning of the canal or near the source are benefiting from infiltrated canal losses always when water is flowing in the canal. After lining the canal these losses disappeared. Some farmers felt this effect as being detrimental for them (Carvalho *et al.* 1986; Portela 1985).

Another case is that the lined canal only allow access to water to plots with special constructed concrete inlets that are closed or opened by iron sliding gates. There are however plots that do not have an official right to water but accidentally or permanently gain access through exchange or other transactions. Not seldom farmers destroy the lined canal at that place to improvise an inlet (Malta *et al.* 1994).

The effects of canal lining and the interdependence between water sources is also mentioned by Boelee (1992) for the village Romainho (see Chapter 3.1). In the downstream part of the main canal some nearby springs definitely give less water or even ceased to give water at all. That must be due to the lack of infiltration out of the lined canal to downhill springs. In the villages of Sezelhe and Póvoa de Lila, the MRT intervention affected the availability of water in systems situated downstream. The lined canals eliminated the losses which fed these downstream systems (Malta *et al.* 1994). In the hamlet of Santiago due to the construction of a concrete intake weir, no more leakage water passes to downstream water users (Bleumink and Kuyk 1992). Davidse (1991) mentioned conflicts about the individual capturing and exploitation of springs in privatised *baldio* lands. Some water users said that this reduces the flow of the brook which is the water source for the largest FMIS in the village Pereira.

Considered at village level, nearly all available scarce summer water is used in one way or another which is proved by the fact that in the Summer period practically no flow occurs in the downstream reaches of the local streams. In such situations in which water leakages from channels are used anyway by farmers it can be questioned to what extent the MRT intervention can be considered a productive investment. In these cases the MRT intervention has only redistributive effects. This contradicts the claim of MRT as being a pure technical intervention.

From a regional perspective all irrigation water sources in the summer within the reach and technical possibilities of the farmers are fully used. The other regional water resource, i.e. the Summer flows of the regional rivers[10] (Douro, Tamega, Tua, Sabor, Corgo, Cavado) are needed for use in other sectors (generation of electricity, State-managed irrigation systems, minimum flows necessary for navigation and ecological reasons). Moreover, in farmer-managed irrigation these rivers are difficult to use because they have cut deep, narrow valleys into the landscape leading to large differences in topographic level between river beds and irrigable lands which would imply very high investment (high dams, long supply canals etc.) and/or operation (pumping) costs.

From the foregoing I conclude that even from a technical viewpoint the MRT intervention, i.e. canal lining cannot be considered a purely technical 'neutral' intervention in order to eliminate physical inefficiencies. Because of the interconnectedness of local water sources, 'putting concrete' does not result in more irrigation water at village level but has mainly redistrubitive effects in many Trás-os-Montes' villages. Conceptually these effects are similar to the redistribution of water which occur when traditional water sources dry up as a consequence of the installation of new individual water sources. *Whether these effects are desirable or not and for whom cannot be determined from technical rules alone*. The whole local context needs to be taken in account.

An unproductive use of irrigation water?

The third assumption that water in these irrigation systems is not productively used has no empirical basis nor theoretical fundament as I will try to show. Gusmão *et al.* (1987) stated that as an effect of MRT 'remarkable amounts of additional water became available to the farms. However the utilisation of this water is hindered by legal constraints related to the acquired water rights'. From the aforegoing it is clear that the first part of the statement is wishful thinking but the second part seems more inspired by the general idea that by definition these systems function imperfectly as is echoed in the afore-mentioned publications[11] (see Box 6.1). This is clearly reflected for instance in the following statement:

> 'the development of irrigation is inferior compared to the hydrological potential and the crop water needs. Although considerable areas exist which are irrigated by traditional irrigation schemes- in which the water is communal, going around and the crops benefit by one or two irrigation turns seldom adapted to the vegetative cycle of the plants - *the truth is that in these circumstances the irrigation water is frequently more harmful then beneficial*. One irrigates when it is one's turn and not when the crops one pretends to irrigate demand the application of water' (Vilhena de Gusmão 1985:181, 182; emphasis added)

This is really a strong statement[12]. It can be examined on different levels. First on a technical level, therefore I will use the irrigation scheduling program CROPWAT (FAO 1992). In Box 6.3, I compare the effects on the variation of the soil moisture in the root zone during the growing time and the calculated yield reductions of a maize crop without irrigation (rainfed) and with the two irrigation turns mentioned in the statement above. From this comparison it can be concluded that contrary to the statement even two irrigation turns result already in a higher average soil moisture level during the growing season and a higher yield level.

The statement however suggests that the actual irrigation practices are very inefficient and had better be replaced by others. It is interesting to note that in the publications comparting the same ideas (see Box 6.1) I never came across a viable proposal or solution to make these irrigation systems more efficient or productive. Apparently the authors of these publications themselves have no idea how to improve the so called 'faulty' management of these systems. It seems that they see no solutions within the context of these systems[13]. In Chapter 7, I will show that it is possible to improve actual irrigation practices, not replacing them but based on them and developing them further.

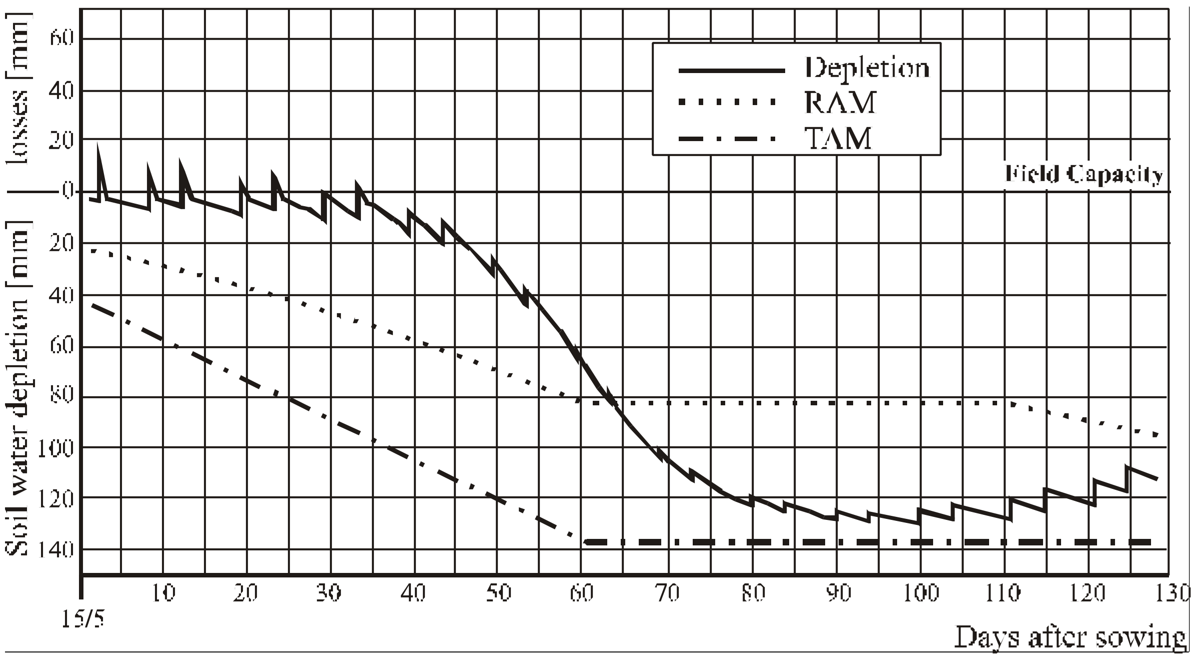
Box 6.3 Comparison between rainfed and 'two-turns' irrigation

I will illustrate the difference with the irrigation of a maize field of 0.12 ha.
Assumptions for simulation:
- Soil type: loam (Total Available Moisture: 140 mm/m) and a soil depth of 1 m
- Climatic data: ETo and average rainfall of Montalegre (see Appendix III, Table 1)
- Crop: grain maize (see Appendix III, Table 6) ; planting date: 15/5

Rainfed Situation

Relative yield reduction: 80 per cent
soil moisture status during the growth season: see Graph below

Variation of soil moisture in the root zone during the growth season



Note:
For an explanation of concepts used in the Graph, see Box 5.3. The 'saw tooth' line is the result of the initial soil moisture content at time of sowing (it is assumed that the whole potential root zone is at field capacity as result from former rain), rainfall and water withdrawn by the crop. Note that the crop is mainly surviving on basis of the previously stored soil moisture. From about 65 days after sowing onwards serious water stress will affect considerably crop yield

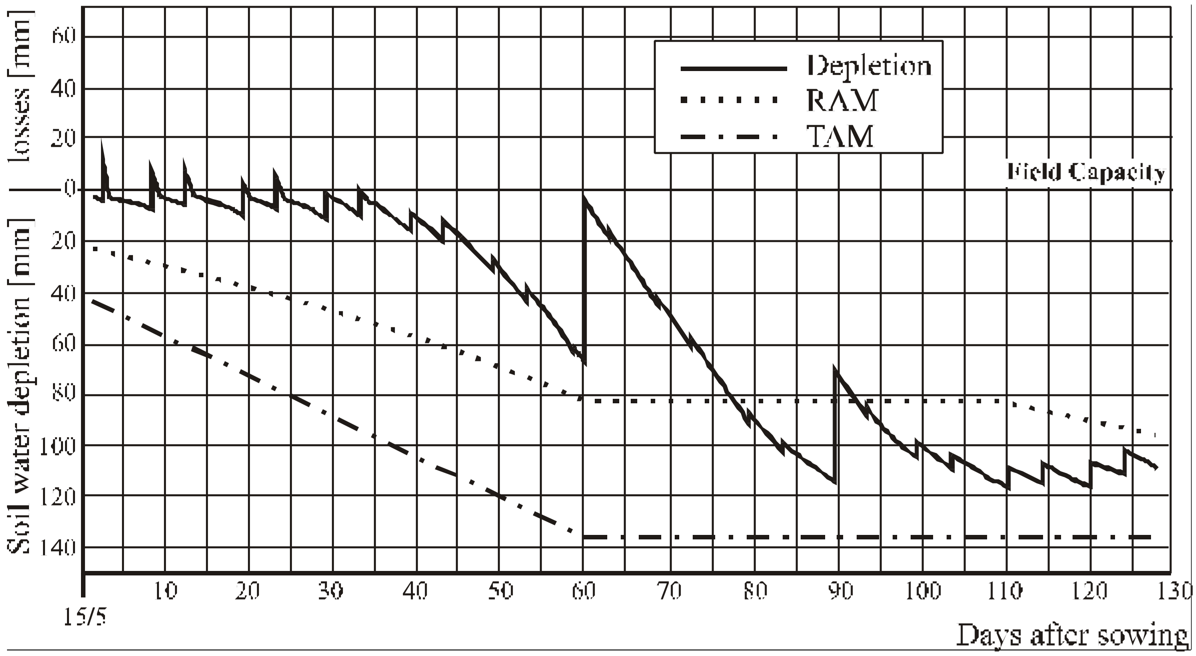
'Two-Turns' Irrigation
- length of irrigation interval: 30 days; Two irrigations: 14 July and 13 August
- water right for this plot: 2 hours/30 days
- hydrograph of water source (see Appendix III, Figure 1)
- field at head end of system (canal conveyance losses neglected)

These assumptions result in the following combinations of irrigation dates, source flows and irrigation depths

14–7	11 l/s	66 mm	13-8	7 l/s	42 mm

Results from simulation:
Relative yield reduction: 35 per cent
soil moisture status during the growth season: see Graph below

Variation of soil moisture in the root zone during the growth season



Note:
For an explanation of concepts used in the Graph, see Box 5.3. The two irrigations take place respectively on day 60 and 90 after sowing. In comparison to the rainfed case, water stress is less and stress periods are shorter (from day 80-90 and day 95-130 after sowing compared to 65-130).

In the situation as it is now, each farmer has the right to use in the summer a share of the available irrigation water. Through the system of water rights (allocation principle) he knows beforehand when he will receive water and approximately how much. So he is able to make his plans for crops and irrigated areas accordingly. Because in most Trás-os-Montes systems, irrigation water in the summer is relatively scarce in relation to land, farmers tend to irrigate a larger area than calculated by the necessities of optimal irrigation for maximum yields. This leads to an optimisation of the resource water[14]. Crop yield (kg/ha) is not the criterion, instead it is production per unit water or the water use efficiency (kg/m^3 of water). The general practice of underirrigation in the summer is a very clear manifestation of this tendency (see Chapter 2). So, contrary to the assumption of an inefficient or unproductive water use, this practice points to an efficient use of the scarce water[15].

Apart from these technical aspects, another, perhaps still more important aspect is mentioned by Ostrom (1992:56):

> *'Sequential rotation, which is frequently used in farmer-managed systems, is criticised by irrigation engineers as being too rigid and technically inefficient. If*

> *a farmer has a higher-value use for available water but is not next in line, it is difficult to adjust these sequential water distribution systems to deliver water to whoever will receive the highest value from it. There may be other factors to consider in evaluating the allocation rules of an irrigation system besides the short-run efficiency of water use. If farmers cannot effectively monitor an allocation scheme at a relatively low cost, short-term efficiencies can rapidly be lost as monitoring declines and improper allocations (theft) rise.*'

So, what from a purely technical-economical perspective could be perhaps considered as being inefficient, can be the most optimal and sustainable from a farmer's management perspective. It is especially low transaction costs and easy monitoring that make the difference.

In general, flexible demand-based irrigation scheduling and management based on crop water requirements, diversity in soils and changing cropping patterns which delivers water approximately in agreement with the higher-value use is incompatible with the water distribution in FMIS based on shares. Demand-based systems need another irrigation infrastructure with adjustable structures, a constant feedback from field conditions to adjust irrigation distribution and a complex scheme management[16] (water rights, rules, regulations, human intervention). If in these Trás-os-Montes' FMIS demand-based irrigation were be introduced the efficiency gains need to be large enough to compensate for the increasing social cost (transaction cost) and uncertainty related to the development of a new set of rules for water delivery. For reasons as already mentioned in Chapter 5 the increase of transaction costs will be prohibitive to introduce demand-based irrigation scheduling in FMIS of Trás-os-Montes.

Meanwhile, the impossibility of introducing demand-based irrigation scheduling in FMIS of Trás-os-Montes does not mean that water is not distributed according to its value. The much applied practices of exchange of water turns (always possible when third parties are not injured), the exchange of water against other resources (reflecting the different resource endowments and production objectives of farmers' households), the increasing application of night turns on meadows (the common irrigation method of meadows, i.e. contour ditch irrigation, requires less attention on the part of the irrigator, his presence can be even dispensed with if the meadow plot is well prepared, see Chapter 2.3) point all to the differential value of alternative water uses and the subsequent flexibility in water delivery. But flexibility is achieved in other ways than through a far-reaching institutional change of these irrigation systems. Flexibility in these systems is embedded in the framework of the existing working rules and farming systems.

6.2 The Impact of the MRT Intervention

The MRT intervention only marginally contributed to the production objectives of the PDRITM development program. A reconversion of traditional agriculture did not take place. In PDRITM phase II official documents it is clearly recognised that 'the adoption of improvements by farmers such as changes in cropping patterns in newly irrigated areas has been slower than expected' (World Bank 1989). Actual farming practices are still adjusted to the specific place and time dependent availability of irrigation water.

For most farmers the MRT intervention generated positive albeit limited and heterogeneous results. For them the MRT intervention principally meant a cheap upgrading of their systems, linking up closely with improvements implemented by themselves, local initiatives and former requests for support. But they will sometimes ironically add that the interventions somehow came too late, that they had been most needed before the massive emigration: '*the (improvement) works are a good thing but should have been done when I was young ……40 or 50 years ago*' (irrigator of Padroso, quoted in Portela 1990).

This is also reflected in comments by technicians of DSEA that the MRT-interventions are not economically viable, that the interventions have nothing to do with creating perspectives of development but must be considered as social benefits for the habitants of the villages[17].

The MRT as a standard intervention practice, aimed at reducing water losses through lining of irrigation channels, operated in a heterogeneous, diverse environment. This heterogeneity was reflected both in the implementation process[18] and the impact of the MRT interventions. In this section I will focus on the outcomes and effects of the standard intervention practice in the diversity of irrigation situations. This multi-level diversity concerns the physical and socio-economic context, farming, water sources, irrigation water management and dynamics as already discussed in Chapter 2, 3 and 5.

Uniform interventions creating variety: Effects of intervention in the field

In general water users speak with appreciation about the benefits of the MRT component (Portela *et al.* 1985; Portela 1987a, 1990). The interest of the water users is also reflected in the great number of requests for the MRT intervention (400 requests till 1990). Water availability at system level has increased, especially during the summer period, which prevents crops from wilting. Another important effect is the reduction of the labour burden related to irrigation activities as will be explained in detail later in this section. Many farmers mention this effect as the main result of the intervention (Portela *et al.* 1985, 1987b, 1990).

When taking a closer look, however, there is more to say about these outcomes. Under this general appreciation it shows that effects are far from equal for different systems and different water users, and that effects in terms of production appear to be limited. Insights in the causes of these effects can provide suggestions on how to improve intervention actions. For such an analysis the effects should be understood as the outcome of the intersection of the standard intervention package with the existing diversity in the field.

** Design and construction of Irrigation facilities*

Most physical constructions made within the existing irrigation systems are technically not very complicated. Intakes, small canals, small reservoirs (« 200 m3) and field inlets have been constructed. Some problems were a consequence of the underlying design assumptions mentioned before (see Box 6.2). The main conceptual problems encountered were in situations, principally in the mountain zones, in which water is used in multiple ways, whereas design was based on single-purpose summer irrigation. In such cases farmers complained about the small size of the canals, which were not suited for large stream flow winter irrigation (Portela 1987a; Rocha e Silva 1988; Strijker 1992). Another example is given by Strijker (1992): the construction of a concrete tank floor inhibited the water from several springs to enter the tank, thus reducing the original incoming water flow. In some other cases adjustments had to be made to enable washing or animal watering.

** Effect on water availability*

In the first place it must be noted that the MRT intervention is not relevant for *lameiro* (hay meadow) irrigation because outside the summer months water for irrigation is generally abundant.

In general the rehabilitation works have resulted in a greater availability of water in the summer period. By way of lining the conveyance and reservoir losses were reduced. But the system improvement has had no effect on the regime (regularity and reliability) of the source flow. Temporary water scarcity at source level is not influenced by the improvement. With decreasing flows of the source during summer the relative effect of improvement is also decreasing. In some systems (e.g. in the village of Ponte) source flow still dries out in the first weeks of July; lining has only resulted in one more week in which the stream flow could reach the tail end of the irrigation system.

Comparison between systems

Between systems there are great differences as to the extent of increase in water availability. In some cases increases have been substantial as e.g. in Póvoa de Lila, a previously abandoned system. In other cases the investment has had minor effects. Although relative increases might be about the same, absolute increases differed sharply due to differences in initial stream flows, which are clearly linked with the agro-ecological zone the systems are located. A simple example may illustrate this, comparing a typical irrigation scheme from the Mountains and one of the High Valleys.

Irrigation scheme:	*High Valleys*	*Mountains*
Source flow:	1 l/s	20 l/s
Before improvement		
losses:	50%	50%
Available water:	0.5 l/s	10 l/s
After improvement (canal lining)		
losses:	10%	10%
Available water:	0.9 l/s	18 l/s
Incremental available water	*0.4 l/s*	*8 l/s*

The differential productive effects of lining are in these two cases very clear. This same example shows that in many cases increases of water availability in absolute terms were really limited. Especially in the High Valleys, the relative importance of the improvement must not be over-estimated. Schultink (1993) convincingly shows that for most water users in Sesmil (a High Valley village), increased water availability of the rehabilitated system was but a small percentage of their overall water availability.

Individual or group wells contributed far more to overall water access. In one case a user received from the communal system on average some 2.1 m3/day (July 1992) while her shallow well yielded approximately 3.7 m3/day which corresponds with 65 per cent of her total water supply. In this village, the contribution of scattered individual water sources is, roughly estimated, about 80 per cent of the total water supply in the summer. A similar situation is general in other villages of the High Valley zone.

** Effect on water allocation and water distribution*

Assuming that the overall effect of the MRT interventions is an increase of available water, I will analyse these effects in more detail. Two questions are raised. First, at the level of water allocation, that is to say the differention in benefits for water users of the incremental water after intervention. Second, at the level of productive changes: here, the most important question is whether the increase in water has induced an increase of agricultural production, and especially of irrigated fodder for milk production as was foreseen.

From the available data I conclude that on both these levels there is a strong link between the allocation principles and the effects of the MRT programme. Before entering into the details it is necessary to say that the interventions have hardly induced any changes in water allocation. The prior allocation principles and distribution rules were applied to the division and use of the extra water too.

The allocation of extra water

In Table 6.1 the changes in access to water as effects of the intervention are summarised. Table 6.1 shows that in variable time share systems (type 1) the effects in the allocation of the extra water among the water users are most differentiated. In such a system, water users with large time shares gain more extra water than those with smaller shares. Under equal time shares (type 2), the benefits are equal for all water users. In a system with plot-based allocation (type 3), users continue to irrigate the same plots, but increased water flows reduce delivery time and length of irrigation intervals. In systems with no quantitative basis for allocation, it is unclear how much every water user benefits from the extra water. Households with more resources than others (for instance, those with a labour force to wait for their turn under ‘first come, first served’) probably benefit most from the extra water.

Table 6.1 Effect of intervention on farmers with large vs. small irrigation time allocations and large vs. small plots

Water Allocation principle	Criterion for identifying improvement	Size of resource	Before improvement	After improvement	Gain
1. Variable time shares	Quantity of water supplied (q)	Long irrigation time = 10q Short irrigation time = q	10q q	20q 2q	10q q
2. Equal time shares	Quantity of water supplied	Larger plot Smaller plot	q q	2q 2q	q q
3. Plot-based	Irrigated area (A)	Plot size = A Plot size = 10A	A 10A	A 10A	Reduced irrigation interval
4. No quantitative basis	?	?	?	?	?

Note: In the Table it is assumed that the reduction of channel losses as result of the MRT intervention doubles water availability.

It is clear that the MRT intervention could have contributed to the increase of the existing socio-economic differentiation at the local level. Not only because of the difference in water rights between water users but also because only a part of the inhabitants were involved in most improved systems. The first phase of the inventory study has shown that only in 2 of the 22 villages under study, the improved communal system was used by all village members (Bleumink *et al.* 1992). In some cases, up to 50 per cent of the families within the village did not have access to the improved communal system at all (Bleumink *et al.* 1992). A clear example of an increase in differentiation is the mountain village of Corva where 3 out of 55 families have rights to 66 per cent of the water in the improved FMIS. It is also these families who explored most private water sources (Bleumink *et al.* 1992).

On the other hand, many communal irrigation systems, principally in the High Valleys, are not dominant at village level. MRT interventions in these systems will not contribute much to the above mentioned differentiation. For instance, in Adães a successful emigrant -returned from Brasil- had little access to the communal system(s) but succeeded in monopolising a large amount of the other water resources in the hamlet and moreover to affect the sources of these communal systems. There is also another reason that the differentiation effects of MRT could be small. Someone with a small farm area and much water rights could achieve the same production as another farmer with much land and limited access to water. Whether such a situation occurs regularly is not known but it shows that a reallocation of water rights does not automatically mean a more equitable situation within a village (Bleumink *et al.* 1992: 68).

The difference in water gains could also imply a differentiated use of the incremental water. The large water user has more room to use this incremental water to extend and intensify irrigation of meadows and fodder crops, and thus for the farm development envisaged by PDRITM, than the small water user, as is illustrated by the following simplified example:

Water users	A	B
- Before improvement		
Total available water	q	10q
For household consumption	q	q
For cattle feed	-	9q
- After improvement		
Total available water	2q	20q
For household consumption	q	q
For cattle feed	q	19q

Even if a large water user is not interested in a further expansion of cattle production, the incremental water is a valuable asset. It is a very valuable means of exchange. Moreover land with irrigation water is highly valued and can be rented out against high fees.

Impact on productive changes

Another important question is the extent to which the improvements have created incentives for changes in water use, especially in relation to the production objectives of the programme. The overall programme essentially aimed to increase fodder production, through an extension of the irrigated area. This objective, however, was rarely attained. This was partly caused by the restrictions that some allocation principles had on the decisions how to use the additional water. Table 6.2 summarises the programme's effects on water use under the different types of water allocation.

Table 6.2 Effects of intervention on water use

Water Allocation Principle	Effects of interventions on production		
	Increase of irrigated area	Increase of pastures	Exchange/commerce of water
1. Time shares	Incentive	Incentive	Incentive
2. Equal time shares	Incentive	Incentive	Incentive
3. Plot-based	Restricted	Restricted	Restricted
4. No quantitative basis	?	?	Restricted

Systems under time allocation (types 1 and 2), basically offer farmers most flexibility to use adequately the additional water. The canal lining not only reduces conveyance losses but also travel times in the canals. These effects diminish the earlier problems associated with using the water on preferential plots and crops (see Chapter 2 and 3). In these systems it may be expected that farmers use the extra water in the way most convenient to them, related to the objectives and possibilities of their whole farming system.

In practice, increases of the irrigated area have hardly been encountered. This is primarily due to the minimal increases in discharge, which hardly allow extension of the area. The additional water is applied to the fields irrigated already, where now major water depths are applied. Shifts towards more production of irrigated fodder occur, but are infrequent. Some farmers who had made this shift affirmed that it was made possible by the availability of additional water, in combination with the subsidies for investments in animals and machinery. Other farmers attributed this shift to the decline in the demand for food crops, which created space for fodder production on arable land.

Under plot-based allocation (type 3), water use is conditioned by more rigid rules. The plot-based arrangements do not allow farmers to increase irrigated areas or to irrigate temporary meadows. This makes it impossible for farmers to adjust their practices in the direction of the programme's objectives. Still, irrigation of plots may be intensified by applying the same water depths in shorter irrigation intervals.

Where no definition of the allocation exists (type 4), changes in water use are difficult to predict and largely depend on the local situation.

Notwithstanding the frequently unequal benefits and the rigidities of allocation, there has been little discussion about on whether to change water rights and allocation principles under influence of the MRT activities. The increase of water availability, due to these activities, is generally limited. Although there is more water, existing water users still could not irrigate all their plots optimally. This possibly could restrain the process of negotiating water rights (Bleumink *et al.* 1992:68). Someone will more likely negotiate about resources if they are less scarce. Water rights frequently being property rights, they will not be very different conceptually from land titles or the property of other valuable resources.

Although some people had expectations that they could gain water rights by contributing to the construction works, it didn’t work out that way. Only in the village of Sesmil, the rehabilitation process gave way to fundamental changes (Pinto Marques 1994). Within this village the existing water rights were already under discussion, and rehabilitation was used as a timely event to reformulate the rules for allocation. The individual participation of each water user in the construction work was used to underpin the legitimacy of the newly established rules. In the definition of the new allocation it was assumed that the MRT intervention would result in an increase of available water by 100 per cent. On the basis of this assumption the original water rights in time shares were halved so that the original water right holders ended up with the same quantity of water. The other half of the shares were divided proportional to the labour contributions of the people in the improvement works. In this way some people gained access to water which they did not have before (Pinto Marques 1994)

In some systems with plot-based allocation the rigidity that the allocation principle imposes on water use has been questioned. Some of the farmers who intend to invest in increased animal production (milk or meat) initiated a discussion to change the allocation principle towards time shares, which creates more flexibility in the decision making of individual farmers.

** Effects on agricultural production*
Contrary to the assumptions underlying the MRT interventions, the increased water availability has not had the results presumed in the project documents (World Bank 1982:17): i.e. a substantial increase in production of forage from irrigated pasture and/or increase in irrigated area[19]. Hard data about yield increases are hardly existent. One case study (Rebelo 1987) show yield increases of maize plots to be directly related with increased water availability at plot level. But technological changes in maize cultivation (e.g. use of hybrid varieties) hardly took place[20] except for the 'modernisers', representing the exogenous farming style. For them summer irrigation of fodder crops became a very important practice as has be shown in Chapter 5.

Another method to have a general idea of the productive or yield effects of lining is to compare the effects of the difference in water availability between an unlined and a lined canal at the level of plant-water-soil relationships. This can be simulated with use of the CROPWAT programme. Outcomes of this simulation show that for maize on loam soil lining could result in a yield increase of about 45 per cent with an increase of the water availability of 60 per cent assumed by the PDRITM technicians. Simulations with other soils (sandy soil with limiting depth of 60 cm), other crops (potato), *ceteris paribus* (20 day interval, same source flow pattern, climate etc), show that estimates of yield increases range from about 20 per cent to 40 per cent with the same 60 per cent increase of water availability. These outcomes suggest that yield increases are less than proportional in relation to the assumed increase in available water due to lining.

For many farmers the MRT intervention was not related to the context of agricultural conversion implying the increase of fodder production and the number of cattle. (Irrigated) farming is in relative terms increasingly carried out by pluriactive and old farmers, some of them in the process of retiring gradually and reducing activities. Shorter travel times of water in the canals made it possible to irrigate specific preferred plots. In some cases this has even led to a contraction of cultivated land because the same household food needs can be produced on a smaller, more intensively irrigated area on plots near the homestead (Stam 1993; Schultink 1992). As such the MRT intervention allowed households to adapt their farming to the shortage of labour[21].

As became clear in practice, for many farmers (e.g. pensioners, pluriactive farmers) the reduction of the labour burden related to irrigation activities[22] was more important than increased production. In some cases the increase of canal water did not lead to an increase of the irrigated area, but rather substituted for a decrease in the use of water from shallow wells leading to lesser pump costs (Portela *et al.* 1985:17). For others, irrigation water was not the only limiting production factor, since access to land and labour was also limited. Finally, production perspectives were not valued positively by all farmers because farming is not considered an economic attractive activity as compared to what can be earned outside agriculture.

It can be concluded that in general farmers have used the greater availability of water to improve the irrigation of traditional crops and to make traditional irrigation practices more flexible.

A third factor that induced the limited productive success was the very weak integration of the different components of the PDRITM project. Although in theory MRT is not an autonomous component but an instrument in combination with other components to realise PDRITM objectives (integrated development), in many cases MRT was an isolated action, not linked to other supportive activities like the construction of a village milking parlour, extension services or credit facilities and vice-versa. Such interventions mostly did not result in synergic effects. A whole series of examples can be given. Irrigation systems have been improved where necessity is felt less than in other hamlets such as for instance Adães[23] where conditions have been created for milk production through the building of a collective milking parlour (SCOM). The same happens with the improvement of rural roads. In other villages SCOMs were built that never functioned. Various interventions could even have contradictory effects. A clear example is afforestation, which in some cases 'dried up' water sources on which improved irrigation systems depend. It happened in Soutelo and Sta. Marta de Alvão that sources flowed again when the forest burned down. Local needs and priorities might be different even related to water supply. An example is the hamlet of Mourilho from which many inhabitants migrated. The resident households seemed to have enough water to continue their actual production system. They were very interested in a reservoir which may serve for the fire fighting[24] instead of the improvement of their irrigation scheme (Portela 1984).

* *Effects on labour input and workload*

The most important effect of the MRT intervention is the reduction of required labour input. A decreasing labour input, time and workload/ drudgery of the irrigation practice as result of the MRT intervention is mentioned by most water users (Portela *et al.* 1985, 1987a, 1990). Irrigation is less time-consuming and involves less physical effort and hardship. Before improvement the water users frequently had to walk long distances to the water source, open the reservoir, guide the water in the earthen canal to the plot inlet before the water could be applied to the field[25]. In some schemes, source and canal patrolling is necessary to prevent other users from taking water. Because of small canal discharges, field irrigation required a very intensive labour input. In other schemes with continuous running water (see Chapter 3.2) it was necessary to irrigate food crops at night. If the improvement of the irrigation system resulted in a higher water availability, food crops tend to be irrigated in day time while pastures could be irrigated during the night which requires less labour (contour flooding irrigation method). Even in cases that water is stored during the night, work conditions improved: the opening of small paths along the canals required for the lining works and the construction of new reservoirs made the operation of irrigation more simple and less time consuming because in some cases time needed to walk to the water source or the reservoir diminishes. Also the time and labour-consuming guiding of water to the plot decreases. Higher streamflows available at plot level lead to a decrease of labour input for the same quantity of applied water/ water depths thus lead to a higher labour productivity of field irrigation activities. Also the labour needed for maintenance of the system and the reconstruction of temporary weirs has diminished[26].

6.3 Conclusions

On the level of assumptions

From the analysis of the underlying assumptions of the PDRITM irrigation interventions (Chapter 6.1) it can be concluded that the MRT intervention aiming at creating the conditions for the modernisation of agriculture is not or only marginally adequate to respond to this goal. This is for instance reflected in the comment of a farmer with 40 cows about the MRT intervention in his village (quoted in Portela *et al.* 1987:16): '*The works (intervention) will not resolve nothing. It doesn't stimulate the production for the market. The money was badly spent. What is needed is to make a dam to have water for meadows to feed the cattle*'.

The MRT will not yield substantially more water in the Summer because the initial assumed available water is simply not there. Moreover, the examples in this chapter show that canal lining is not at all a guarantee that water availability would be substantially increased. The flow measurements show that in some cases lining could even result in less available water at system level. The *MRT intervention does not create more water but redistributes existing water*. With or without intervention, summer water remains a scarce resource whose distribution is governed by social agreements and historically created rules. In synthesis, for the development of the exogenous farming pattern the MRT intervention has not brought substantially more water neither the new labour-saving technology and the closely interlinked reorganisation of space, nor changes in the management of the systems.

Thus the following question emerges: if MRT is not an adequate response to the development needs of the modernisation pattern what are then the conditions and perspectives for the type of irrigation development as required by the modernisation pattern?

In the first place, the modernisation pattern can be characterised as frustrated development: socio-economic and ecological conditions in the region structurally hamper the development of the exogenous pattern. The modernisation pattern does not fit the existing environment, it is necessary to create a new environment but that is hardly possible. The contradiction between modernisation and environment cannot be remedied in this way. In conclusion, modernisation as envisaged by PDRITM becomes blocked by its own contradictions.

In the second place, although the exogenous farming pattern implies an inefficient water use in terms of resource use, that is of income and production generated per unit of scarce water (see Table 5.2), its development and the support for it might lead to an increasing competition for the scarce water resources. Also taking in account the increasing demands for drinking water etc. the encouragement of exogenous farming development patterns might lead to undermining of already existing irrigation systems, over-exploitation of groundwater supplies and a creeping process of redistribution of available water resources. These processes are even boosted by an additional state support program (PRI) that heavily subsidises investments to develop individual water resources. No criteria exist to avoid interference with traditional water sources.

Moreover this program is highly selective because subsidies are linked to investments already done in the framework of the ‘797’ projects.

The only adequate intervention for the modernisation pattern seems to be the construction of medium-scale irrigation perimeters (NRC) in conjunction with dams. This intervention will create new water by storing excess winter water. But even when the problem of water availability is resolved, other problems will pop up like the scattering of plots that inhibits an efficient water distribution and labour-saving irrigation practices[27].

On the level of actual interventions

MRT is an example of a means-centred intervention as compared to a goal-oriented intervention. That means that the intervention is not related directly with the desired goals (related with agricultural development) but defines the means (lining irrigation channels) assuming that the goals will be realised in a deterministic linear cause-effect relationship. In heterogeneous contexts, such goals can only be realised in differentiated ways, with differential means, instruments, assistance and interventions. Government agencies related to agricultural development tend to produce and prescribe uniform instruments, means and types of support to realise certain goals, to produce uniform interventions and investments. As such, it is assumed that there is only one way to realise a goal. Neglecting the existing diversity results in rather heterogeneous outcomes. These outcomes are either random or highly selective. The principal benefits from development efforts are allocated to actors who are eligible for the specific type of institutional assistance thus who are able and willing to integrate these means and solutions in the structure and development of their farms.

As has been stated before, farmers in general make a positive, albeit heterogeneous assessment of the MRT intervention. The three key elements of this assessment are an increase in available summer water, the reduction of irrigation labour and the upgrading of the systems. Crucial to the intervention work has been that the respect for both customary rights and established layout of the systems did not raise patrimonial and managerial uncertainties, and did not feed conflicts among water users. In most cases the improved infrastructure has been integrated without many problems in the functioning of the irrigation systems. In fact this has been a clever, however limited option[28] from an institutional viewpoint and a major shift in irrigation policy in Portugal, which has undoubtedly contributed to the positive results of the rehabilitation work.

At the same time it should be realised that the contributions of the MRT intervention to the improvement of farmer-managed irrigation in Trás-os-Montes have been very modest. First, water is generally not scarce outside the summer months so the prevention of water losses by means of lining is not relevant in that period. Thus, the MRT intervention did not contribute to the expansion and quality of *lameiro* irrigation. That represents 2/3 of the total irrigated area in the Mountains and 1/3 in the High Valleys (see Table 2.3).

The increase of available water in the summer months as a result of the MRT intervention has been very low in many cases. In 19 out of a random sample of 28 communal irrigation systems this will not be more than 0,5 l/s in the driest month (van den Dries and Portela 1994).

In most cases the distribution of extra water (and thus of public investment) has been very unequal among the village inhabitants. These facts call into question the efficacy of the interventions and the perceptions underlying it. A first conclusion is that the MRT component has partly reached the projected increase of water availability, but merely as a technical feature, that is to say with minimal production impact. Moreover, it has been a relatively random outcome, who has been able to profit from this increase.

A more important question is whether this increase in water availability has been reached in an efficient way and has contributed to important local development dynamics. As for efficiency, it has become clear that in some cases the emphasis on only improving the (purportedly) most important irrigation system could not be justified, because of its minor water availability and the involvement of only a minority of the village members. This has resulted in inefficient expenditure of public investment. Another striking example of the MRT restriction to collective systems (be they important or minor) became apparent in a village (Calvão) where farmers have abandoned the collective irrigation system and exploit now a great number of particular water sources (Middelhof 1993). Still, MRT intended to intervene in the abandoned system without having studied or discussed other local alternatives. This results from the narrow concept of improvement/rehabilitation.

The above example implicitly calls into question the often isolated and separated character of intervention in relation to local development, needs and priorities, and the criteria for selection of systems to be improved. This selection procedure is not very clear and subject to pressure on the part of (political) power groups. Selection criteria are more centred on the convenience of the implementing agency. Actual water management and the productive potential of a system play a minor role. Moreover, the increasing need for irrigation water in the villages where farmers tend to intensify production does not seem to be an explicit criterion for selection.

A final comment on the intervention strategy is that (groups of) water users usually were not or minimally (or selectively) involved in the planning and design phases of the intervention. This has led to conceptual errors in the design (e.g. canals that are unsuitable for winter irrigation) and to problems and delays in the implementation phase.

In summary, the effects of the MRT intervention are very heterogeneous both at the system level and the farm level. The intended effects of the MRT intervention as contributing to the transformation of traditional agriculture have not been achieved. It is not an adequate and -at best- a marginal response to the development requirements of the exogenous farming patterns. For most other farmers the MRT intervention resulted in positive but limited and randomly distributed results. Then the following question emerges: can one conceive of alternatives that would strengthen especially the endogenous farming styles and existing FMIS? I think there is a hidden potential in these systems. This will be the subject of the next chapter.

Notes

1 One problematic aspect of the Schultz thesis is the definition of the technical ceiling. A case study of Rebelo (1987) about the effects of the MRT intervention on yields shows an enormous variation in yield levels, for maize a variation between 800 kg/ha and 6,800 kg/ha in 1986 over 29 plots in 5 irrigation systems of the municipality of Vila Pouca de Aguiar (Rebelo 1987: 60), for potatoes between 13.7 tonnes/ha and 52.3 tonnes/ha in 1985 over 25 plots in 5 irrigation systems located in the municipality of Vila Real (Rebelo 1987: 65). Taborda (1932: 84, 85) and Portela (1988: 184) also mention large time and space-dependent, yield variations. Zachariasse (1974) shows that also considerable yield variations occur in relatively new agricultural colonisation regions like the Noordoostpolder in the Netherlands with ‘progressive’ farmers, selected by the government, living in a homogeneous physical, technological and socio-economic environment.

2 In the words of Portela (1991a: 7): ‘*The irrigation calendar of the traditional irrigation system is considered as an impediment and not as a contextual condition which the researcher must integrate in his framework of analysis and solution*’.

3 In a study of the irrigation system of Torneiros, Bleumink *et al.* (1991a) mention that in a preparatory meeting of the planned improvement tailenders raised the subject of the water distribution (‘free-to-take’, see Chapter 2.4) which was highly unfavourable for them. However, the engineer leading the discussion rejected the proposal by saying that they had not come here to change existing customs and rules.

4 Because of the lack of labour many farmers in Trás-os-Montes, even without cattle, are converting arable land into *lameiro*. This is a logical option if there is room for irrigation of these *lameiros* considering the water availability and the existing water allocation principle (*a vez* and *a pilha*) in winter.

5 Vilhena de Gusmão (1985) states that the improvement of the traditional irrigation systems in Trás-os-Montes could result in an irrigated area of 75,000 ha. That is nearly two times the official figure of 40,000 ha irrigated land in Trás-os-Montes (DGRAH 1987) which is probably already an overestimation.

6 However, effects could be different. In Fiães de Tamega the MRT intervention allowed the extension of the winter irrigation to the *lameiros* downstream of the village because the lining of the canal prevents the inundation of the houses and village roads (Portela *et al.* 1985:18).

7 Canal discharges have been measured using the salt diluton method. In this method, the degree to which an added salt solution of known concentration is diluted by the flowing water is used to determine the canal discharge (ILRI 1989). This method is very suitable for Trás-os-Montes conditions because the salt concentration in the natural waters is very low and the normally large turbulence in the canals ensures that the salt solution is thoroughly mixed with the flow. Another crucial advantage is that this method does not interfere with channel flows, distribution and farmers’ irrigation practices. Comparison with other flow measurement methods yielded satisfactory results (Pinto Marques *et al.* 1995:2).

8 Some striking examples are given below. Haagsma (1991) made a study of irrigation in Santo Antao, one of the Cabo Verde islands. Current opinions claimed that local management was archaic and inefficient. Since independence the State invested a lot in the improvement of irrigation infrastructure, principally canal lining. In this way the Cabo Verde government expected to improve the efficiency of irrigation systems and at the same time to create large-scale employment projects. However, canal losses are of no concern to farmers as they are re-used at lower levels. This attitude clashed with that held by engineers. Haagsma discovered that the relatively low system efficiencies go together with high river basin efficiencies through the re-use of irrigation losses at lower levels. An improvement in the water availability of an upstream system might have negative consequences for the water availability in any downstream system in the same valley. The effect of the intervention was not an increase of the overall efficiency but a redistribution of the available water.

Another interesting case is the conjunctive management of surface water and groundwater in the Middle Rio Lerma Basin in Mexico (Scott *et al.* 1999). The 1,700 km2 middle Lerma basin comprises 150,000 ha of irrigated area. The main problem there is the alarming decline of the groundwater level. The researchers came to the remarkable conclusion that bluntly spoken the most appropriate measure to improve the water balance is irrigating as inefficiently as possible with surface water. This clashes clearly with the conventional thinking of irrigation engineers (but also of environmentalists and economists) for whom water saving is now the pillar of their actual professional activities and paradigms (rehabilitation and 'modernisation' of irrigation systems, introduction of water-saving irrigation technologies, agriculture as an inefficient water user, increasing efficiency by getting prices right etc). When this conclusion was communicated to a congress of irrigation professionals the perplexity was total: 'you are right but it cannot be true' was one of the comments which could be heard (pers. comm. Flip Wester).

9 A similar situation is reported by Luuk Fleskens (Pers. Comm.) for South Marocco. There one can see from afar whether a canal is lined or not: in the last case all fruit trees purposely planted along the channel to take advantage of the losses are alive, along the lined canals they died.

10 The R. Douro and R. Tamega have their origin in Spain. It can be expected that the flows of these rivers in Portugal which are already reduced in the summer (INAG 1997) will diminish still more because of the ever-increasing use made of them in Spain.

11 These ideas are also common in national and regional water policy and management circles. In the development plans of two river basins situated in Trás-os-Montes (Hidrorumo *et al.* 1999; 2001) one can find statements like 'the dominant irrigation technology in the hydrographic basin is based on the use of traditional surface methods, hardly evolved and with a low efficiency which cause significant losses by surface runoff and deep percolation. The rehabilitation of traditional irrigation systems made in the framework of PDRITM, PEDAP and PAMAF resulted in significant increases of the available flows for irrigation. However these improvements were not accompanied by correct measures of management and water use like the implementation of new distribution arrangements. An increase of the water availability for new irrigation areas did not occur. Therefore the efficiency of water use continues to be low' (Hidrorumo *et al.* 1999: 26) and 'a large part of the farmers of the region don't consider water as a scarce resource, and therefore they don't adapt practices for a more rational water use' (Hidrorumo *et al.* 2001: 18).

12 But it is time and again repeated in other words. For instance Santos Pereira (in Rego *et al.* 1990) stated: 'in many irrigation systems in the Northeast region the irrigation calendars were imposed due to the scarcity of water, only in function of the individual farm area resulting many times not adjusted in relation to the crop water requirements, the soil characteristics and the availability of farm labour. The increase of the available water (…..) which is proportioned by the MRT intervention, should permit a new management of these irrigation systems'.

13 In the designs of the MRT improvements (DRATM 1981; GAT 1985; Guerra 1987; Fonseca Calvão 1990) invariably, uniform, ideal lengths of irrigation intervals, application depths, application efficiencies and seasonal irrigation requirements are calculated, respectively for potato and meadows. However, these are theoretical paper exercises which result in a type of prescriptions but which have no relation to the physical and socio-economic reality. They are based on underlying assumptions like a constant water availability during the growing season when in reality source flow is decreasing during the summer; application efficiencies of 60 per cent when in reality they are near 100 per cent (see Chapter 2.3). Further, the questions if these different ideal irrigation intervals and application depths fit the existing allocation (water rights) and water distribution or how the actual water distribution need or could be adapted to these calculated intervals and application depths, are ignored.

14 The question of the most efficient or productive use of a limited quantity of irrigation water is a highly complex one with many contradictory, crop and site specific outcomes. First, water use

efficiency depends on the availability of other growth factors (climatic factors, soil fertility, genetic potential etc.). Optimal irrigation will only lead to high yields if other conditions like soil fertility and pest control are also optimised. If these growth factors limit crop growth -frequently occurring in Trás-os-Montes (Thies 1989:130)- then the use of water above a certain level has no incremental productive effects. Second, an additional complexity is that other inputs as e.g. fertiliser can to a certain degree substitute for irrigation water. Third, it depends on one's definition of efficiency or productivity. In agronomic terms it is the physical production per water unit, in economic terms it is the monetary returns per water unit. A certain quantity of water applied on flowers will in economic terms yield more than the same on fodder crops. Fourth, the concept of water use efficiency is only meaningful if water is the limiting production factor. If water is abundantly available in relation to land (e.g. in the winter irrigation of *lameiros*), the concept of efficiency has no meaning. When water is the limiting factor then a maximum production per m3 of water will present the most efficient water use. Numerous field experiments indicated that crop yield (in terms of dry matter production) is linear correlated to crop transpiration (de Wit 1958) and also approximately linear to the crop evapotranspiration (Stewart *et al.* 1977). Thus maximum yield will be achieved at maximum crop transpiration or crop evapotranspiration. Based on this linearity, FAO (1979) define the following relationship: relative yield reduction = k_y*relative crop water deficit. The crop yield response factor (k_y) depends on the crop. If k_y >1 (drought sensitive crops), most efficient water use corresponds to a level of maximum crop water requirements. If k_y <1 (drought tolerant crops), overall production will increase by extending the area under irrigation without fully meeting crop water requirements. When yield is related to the total applied irrigation depth, then a curvilinear, convex function is normal (Stegman *et al.* 1983) in common irrigation practice. That is to say that the crop yield response to incremental irrigation inputs is subject to the principle of diminishing marginal productivity, *ceteris paribus*. This is illustrated by many studies, e.g. from India and Pakistan for wheat production (Taylor 1980: 56,57; Bhatti, n.d.). The dimishing marginal productivity of irrigation water reflect more than proportional field application losses (deep percolation, runoff, residual extractable water or water left over after harvest) with increasing irrigation application depths to realise maximum crop water use levels and maximum yields.

15 That urges for caution to classify yields as low outside the specific context of production conditions. To take an example from protective irrigation systems in Pakistan, most studies stress the low average crop yields e.g. 2.5 tonnes/ha for wheat. However, in protective irrigation systems water, and not land, is the constraining factor. If yields are expressed in terms of production per unit of water it transpires that Pakistan's irrigation systems are not performing so badly, and that average wheat yields lie in the order of 7 kg/mm of water. This is considerably higher than in India, where average production per unit of water for all crops are estimated as 3.2 kg/mm of water (Jurriens *et al.* 1996: 31).

16 Related to the question of the interrelations between water distribution infrastructure and irrigation water management, Horst (1987, 1998) has made some illuminating contributions. Comparing a highly flexible 'modern' system and an inflexible 'traditional' system based on proportional division of water he formulated the *paradox of operational flexibility*. Meijer (1992: 96) nicely summarised this paradox to: '*you need water to save water*'. It means that the theoretical water-saving potential of demand-based, flexible irrigation in which flows are based on varying crop irrigation requirements, will often be offset by water losses as a consequence of the complex management and regulation of such a system, the sensitivity to operational errors and the subsequent conflicts. On the contrary, in an inflexible 'traditional' system, flows are not always coinciding with crop water requirements which could imply water losses (however, not in a condition of deficit or underirrigation which is a normal situation in FMIS in Tras-os-Montes) but the overall water use efficiency is expected to increase due to a simpler technology and a simpler operation (fewer water losses because of a more transparent water distribution, fewer possibilities for mismanagement).

17 While I was doing research in Tras-os-Montes and preparing this thesis I heard some comments along these lines: 'what is the rationale to intervene in these insignificant systems in a region without

development perspective? Giving some old farmers a more relaxed end of their life, a type of terminal care, is that all?' Apart from the simplification of an enormously diverse reality it is this type of discourse on which self-fullfilling prophecies are based. Regions and even whole countries could be written off in this way.

18 The implementation process (selection, design process, execution, contributions of water users, conflicts etc) of MRT interventions in specific villages and in its general aspects is extensively documented in Portela (1987, 1990, 1990a), Portela *et al.* (1985), Bleumink *et al.* (1992), Strijker (1992).

19 Gusmão *et al.* (1987: 1138) state that 'this intervention enabled one to increase the conveyance efficiency (to diminish canal losses) which, on average, reached 90 per cent. In this way farmers may now avail themselves of greater discharges. However the availability of a greater water supply has not always, as one should wish, led to an increase in irrigated areas or production figures, particularly in damp years. In fact, legally one must safeguard acquired rights concerning distribution of water. In other words, though the farmer may have greater volumes of water at his disposal, at times they are not profitably used'.

20 Carvalho and Fragata (1986) state that favourable conditions for the cultivation of hybrid maize hardly exist in the mountainous zones where many FMIS are established. They mention in particular the characteristics of the farming systems, the lack of irrigation water even after intervention, the lack of fertility, the acidity and the existence of toxic aluminium levels in the soils. They opinion that for the majority of the farmers in these zones only improved regional varieties could secure increments in yields.

21 This effect does not seem limited to small scale interventions as the MRT. In a study of the new collective irrigation system of Curalha near Chaves, Hoofwijk (1994:49) states that after 3 years of functioning the agricultural production in this system stayed more or less the same as before intervention. Although the enormous increase of irrigation water by the building of a dam, forming an artificial lake with a capacity of 800,000 m3, allowed for a much higher production potential and a considerable expansion of the irrigated area, farmers reduced their irrigated areas but increased yields.

22 Nuno Gusmão (1993) describes a telling episode from direct observation in the village of Calvão, which is a good illustration of how irrigation practices are affected by the shortage of labour. 'Senhora Lurdes, 65 years old, is going to irrigate her plot of onions (20 m2). She irrigates alone because her husband is treating another plot and her 6 children have all emigrated. It is 9 o'clock in the morning and she starts to clean the canal. After one and half hour she has ended the cleaning. The sun of July is shining without compassion and she has to hurry up to prepare the meal for her husband. So, she derives the water of the brook to the canal. Still she has some time to regularize the furrows within her plot. The approximately 2 l/s which entered the canal from the brook take some 15 minutes to travel the 150 meters of canal to her plot. A considerable part is lost by infiltration. The arriving water is guided to the first furrow but before this furrow is filled, the water is not flowing any more. 'It is the rats' said Sra. Lurdes, 'they don't let us irrigate in peace'. She returns to the beginning of the canal and has to inspect everything till discovering the hole where the water is lost. This situation is repeating itself various times until 12 o'clock. Sra Lurdes has to go home, she is already late, the plot of onions is only half irrigated. She has to return tomorrow for the other half. Formerly, two persons executed this operation. One person controlled the flow in the canal when the other was irrigating'.

23 Paulo Morgado (1992: 19) mentions the ideas of farmers in this village for improving their irrigation systems. It is interesting that they did not ask for an official MRT intervention but for specific support. The only thing they asked for were construction materials. They did not ask for a project nor the intervention of a technician. The farmers themselves wanted to contract a skilled mason, one who was already living in the village. Moreover, they added, this mason discovered a more efficient way to make

the expansion joints between concrete elements (with the use of polystyrene instead of the habitual technique with planks that are difficult to withdrawn).

24 In the past the roofs of most houses consisted of thatch (*colmo*) which is highly susceptible to fire. Taborda (1932: 125) mentions the occurrence of various desastrous fires which destroyed whole villages in Barroso and he referred especially to Mourilhe.

25 The following comments by irrigators (cited in Portela 1990) are telling: '*before the MRT, I lost approximately two hours to conduct the water to the plot. It was necessary to close holes and to pull out herbs. I arrived tired and sweated. Now I need only 10 minutes*' (irrigator from Vilarinho de Paranheiras 1985) and '*the first to irrigate needed 3 hours to collect the water. Now 30 minutes is enough*' (irrigator of Travanca 1985).

26 However the maintenance of lined structures needs more specialized labour (masons) and a shift to monetary contributions for the reproduction of the systems.

27 The degree in which these NRCs and other by the State created irrigation schemes in Trás-os-Montes are used is low in relation to its planned potential. The characteristics and performance of these schemes, the context in which they emerged and the environment in which they are inserted etc. are extensively studied and documented in Baptista (1999: Chapter 6), Baptista *et al.* (1995, 1997), Malta *et al.* (1997), Hoofwijk (1994), Budding (1994).

28 Contrary to that, in many rehabilitation programs of FMIS worldwide, supported by the State, intervention has been extended to 'new' physical distribution structures and 'improvements' in the management of the systems. This has often resulted in disaster. To give only one documented arbitrary example I came across: in the Village Irrigation Rehabilitation Project (VIRP) in Sri Lanka new, more 'efficient' distribution structures were introduced, supposedly to prevent wastage in the system and, therefore, to increase cropping intensity. The efficiency of the 'new' structures is contingent on a relatively abundant water supply. As soon as there is water stress, the new structures introduce inflexibility in the water distribution. Moreover, the new structures are 'management-increasing' structures, that require a different mode of organisation than that currently in operation. Even worse, the imposition of structures that appear to be incompatible with existing traditions and practices may in time destroy the strengths in local organizational and leadership resources that exist (Abeyratne 1990). Numerous other documented cases exist worldwide (Lam 1998; Shivakoti 1992; Hoogendam 1993; Siy 1989; Horst 1996).

7 An Alternative Approach to Irrigation Development in Trás-os-Montes

In Chapters 2 and 3 the skill-oriented nature of farmer-managed irrigation systems and the context in which they are embedded was described. It was shown that the complexity, diversity and dynamics of irrigation practice is rooted in the locality and shaped by local potentials and interests. In Chapter 4 it was indicated that development efforts from the state were directed to a modernisation of agriculture and the creation of 'viable' farms. PDRITM considered irrigation development a basic condition, if not a lever for the transformation of traditional agriculture. In Chapter 5 a comparison was made between the irrigation practices in two contrasting farming patterns. It was shown that the exogenous farm development pattern, stimulated by institutional development efforts, signifies a rupture with ecological conditions and the management of traditional irrigation. In Chapter 6 the basic assumptions underlying MRT, i.e. the most important irrigation intervention, were examined. It was concluded that the (initial) purpose of this intervention, namely to create conditions for the development of modern agriculture, can hardly be realised. Also in Chapter 6 a critical evaluation of the underlying assumptions and the impact of the MRT intervention was presented.

It is now time to present an alternative approach to irrigation development. This contribution can be only very modest because irrigation cannot be a *panacea* for the whole of complex problems facing the (agrarian) development of Trás-os-Montes and other marginalised areas. It can only be a strategic element (interrelated with others) in an integrated approach to rural development.

I will depart from the premise that building upon and improving the local potential of human and natural resources is the basis for sustainable rural development. Under this premise irrigation development is to be based on the potential hold in farmer-managed irrigation and the adaptation of the irrigation systems to a changing context. This will be elaborated at three different levels.

First, I will re-examine the agrarian question in Trás-os-Montes and particularly in Barroso. The standard diagnosis in mainstream policy circles is that too much labour is producing too little. The cause of this (assumed) low productivity in agriculture is the lack of modernisation of the agricultural sector (see Chapter 4). Agriculture had to be transformed by adopting exogenous models to increase productivity and incomes. However, current modernisation projects involve considerable transformation costs. These costs are especially high in the so-called marginal or less-favoured areas. For the 'modern' farm, *an environment needs to be created in which it can develop*. To create this environment massive state support and intervention is needed. I will show that the potential impact, or more specifically the effect irrigation programs have on resource use and employment, is highly dependent on the development approach in which irrigation is embedded. Within an endogenous approach based on the use of local resources the potential to increase productivity and incomes will be significantly higher than in an exogenous approach. But this has consequences for the most appropriate form of irrigation development and the external support to it, which is different from the exogenous approach.

Second, I will present an alternative approach to strengthen local irrigation development. Building on local resources, development perspectives, farmers' knowledge and local dynamics, I will formulate alternative intervention strategies which have the potential to improve actual institutional irrigation interventions (MRT and successive programs).

At a third level, the question of how to translate the needs of adaptation to a changing context into technical design, will be central. How FMIS can be redesigned? A concrete application is the redesign of the Vila Cova' FMIS. I will analyse in detail which (technical) options and possibilities exist to adapt the Vila Cova' FMIS to the changing needs of the users and the changing context characterised by labour scarcity, building upon the actual functioning of the FMIS already described in Chapter 3.2. After the presentation of this specific proposal for improvement I will derive a more general repertoire of the potential for redesigning FMIS. In this way I hope -as an irrigation engineer- to contribute to the development of tools which could be used in the redesign of FMIS.

7.1 A re-examination of the agrarian question

In this section I will return to the contrasting agrarian development patterns embodied in the farming styles of the 'modernisers' and the 'intensifiers' distinguished in Barroso (see Chapter 5)

A rather simple and crude technique was used in a first attempt to reach an impact assessment of exogenous and endogenous development involving an extrapolation to the regional level of the hidden potentials of these contrasting farming patterns.

Based on the analysis of farm accountancy data, I make a very rough estimate and compare which land and water resources are required under the two patterns to obtain the same income per labour unit. This comparison gives an indication of the potential impact of the contrasting farm development patterns ('modernisers' vs. 'intensifiers) on resource use and employment (see Table 7.1). Or in other words, comparing the two contrasting development patterns, it indicates how many labour units could earn a reasonable income from a certain area given its land and water resources and assuming the presence of one farming pattern in the area.

Table 7.1 The potential impact of contrasting farming patterns based on the differential use of land and irrigation water resources

Parameters	Unit	'Intensifiers' endogenous pattern (N=12)	'Modernisers' exogenous pattern (N=6)
(1) Acreage per labour unit	ha/l.u	3.8	6.9
(2) Net income per labour unit	ct/l.u	412	540
(3) Net income per hectare	ct/ha	121	103
(4) Cattle density	CU/ha	2.4	1.6
(5) Cattle units per labour unit	CU/l.u	9.1	11.0
(6) 'scarce' water requirements per CU	m3/CU	140	650
(7) 'scarce' water requirements to realise net income: (5)*(6)	m3	1280	7180
Supposing that the net income per labour unit in the two farming patterns is equal to the average of the exogenous pattern (540 ct/l.u), then the outcomes are:			
(1) Area per labour unit	ha	5.0	6.9
(5) Cattle units per labour unit	CU/l.u	12.0	11.0
(7) 'scarce' water requirements to achieve the same netto income per labour unit	M3	1680	7180

Note: values are averages of the two contrasting patterns

The table shows that the average net income per hectare for the endogenous pattern (121 *contos*/ha) is higher than for the exogenous pattern (103 *contos*/ha). However, the reverse is true of net income per labour unit.

Table 7.1 shows that to obtain the same labour income[1] as under the exogenous pattern (540 ct/l.u) the endogenous pattern requires - *ceteris paribus* (the same price relations milk/meat, input prices, management etc.) - an acreage per labour unit of about (540/412)*3.8= 5 ha or 12 CU per labour unit, corresponding to an increase of scale of ((540/412)-1)*100=30%. If this increase in scale (acreage per labour unit, number of cattle units per labour unit) is possible[2] it follows that the same labour income may be realised in the 'intensifiers' pattern using about 25% (=100*(1-5/6.9) less land resources and about 75% (=100*(1-1680/7180) less scarce summer water than in the 'modernisers' pattern. Extrapolated to a regional level (of Barroso) this means that the endogenous farming pattern –through the improved use of local resources- potentially offers about 40% (=100*((6.9/5)-1) more labour opportunities than the exogenous farming pattern, given the same labour income.

Also Oostindie *et al.* (1995:69) – using a simple scenario study – point out a considerable difference in agricultural employment between the 'intensifiers' and the 'modernisers'. This difference even amounts to about 100 per cent in the case of a 50 per cent price difference between Barrosã (the traditional breed) and anonymous beef.

Although the above-mentioned extrapolation method and scenario study have some major shortcomings[3] they provide a counterbalance to the economic superiority of the modernisation paradigm (Oostindie *et al.* 1995).

Apart from the potential impact on employment and incomes, the farming pattern of the 'intensifiers' is based on the use and reproduction of local ecological conditions and natural resources which preserve and maintain the landscape and physical environment. Moreover, low external input combined with higher output prices implies a higher local value added.

The exogenous pattern claims to increase farmers incomes by transforming farming and production conditions but there are different grounds for questioning the viability of the exogenous agrarian development patterns and their contribution to regional agrarian development in Trás-os-Montes. First, this type of farming is dependent on external input markets and output markets for bulk products. Increasing competition at the global level and the marginal production conditions for large-scale production in Trás-os-Montes offer gloomy perspectives for farms dependent on such markets. Second, exogenous development patterns fail to build on the strong points of traditional farming such as its ecological soundness and use of local resources. On the contrary, new farming practices such as the use of slurry (*chorume* or faeces plus urine and wash water) neglect the crucial importance of organic manure in the reproduction of soil fertility[4] and could potentially have negative effects on the existing ecosystems (E. Portela 1994: 67, 68). Third, the development of the exogenous pattern requires voluminous resources in the institutional and financial sphere. As far as irrigation is concerned, the exogenous development pattern marks a rupture with the traditional use and mobilisation of water. It requires a supply of irrigation water far beyond the amount of water available during the summer months. In Chapter 6, it was shown that there are serious social and physical constraints to increasing the quantity of scarce summer water to any substantial degree. Thus, the development of this pattern implies high transformation costs, both internally and beyond the boundaries of the individual farm. These farmers frequently state that land consolidation (*emparcelamento*) and dams (*barragens*) are necessary conditions for developing their farms.

In conclusion, there is a considerable *potential* for increasing incomes and employment on a regional scale based on the development of the endogenous farming pattern of the 'intensifiers' and this is a crucial condition for preventing the further desertification and abandonment of the rural areas in Trás-os-Montes.

Implications for Interventions and Policy

This conclusion has far-reaching implications for policy and interventions. An active policy of the State is needed to counterbalance the above-mentioned development. Trás-os-Montes needs public investment and support but it is important how to use it most effectively and efficiently. At least, until recently, in the dominant policy circles it seemed that there was only one possible development path in agriculture possible, that of the creation of 'viable' enterprises along the lines of scale enlargement, specialisation, a high use of external inputs and the application of new technologies. However, the number of farmers which benefit from the support given to modernisation along these lines by means of the '797' investment subsidies is very limited because only (full-time) farmers with a minimum quantity of land and irrigated areas are eligible, which automatically excludes the great majority of farmers in the region[5] (Cristóvão *et al.* 1994). Also the access of the majority of farmers to other sources of support related to EC regulations, for instance PEDAP subprograms, is limited, however htat access is less restrictive than the '797' investment grants. The small farms were considered like an anachronism, economically irrelevant or inviable (not fitting into the 'progressive' or 'European model'). In this way the exogenous development path marginalises not only local natural resources but also human resources. As such, 'modernising' according to exogenous models is a deadlock.

At the same time, other development paths born from within the rich heterogeneity of farming in Trás-os-Montes aimed at the use and valuation of local resources ('intensifiers'), the diversification of income sources (pluriactivity[6]), an intensification based on fine regulation (SCOM farmers in the High Valleys, see Box 5.1) or a combination of these elements, are ignored or considered transitory[7] (Baptista 1999).

For a balanced rural development it is necessary that the diversity of farming is the starting point for a suitable policy of rural and agricultural intervention. State support, which at least until recently had been almost exclusively concerned with the development of exogenous farming patterns, must be reorientated to support the development of endogenous farming patterns, the revitalisation of local resources (*baldios*, local breeds, *lameiros*, FMIS etc) and in a broader sense to link up with the real developments taking place in Trás-os-Montes' agriculture (lack of labour, migration, ageing of farmers, pluriactivity, extensification). Instead of supporting the modernisation path aimed at specialisation, a mode of development must be supported which aims at more (economic) diversification of farm activities but also on a regional level (including afforestation, pluriactivity, quality production, rural tourism etc.)

But this reorientation need to overcome many obstacles and 'hindrances'(see Box 7.1) to endogenous development (or to realise the *endogenous potential).* It raises many questions about which support is needed, which instruments are the most appropriate for implementation, how, where and when to apply etc. It lies outside the scope of this thesis to deal with all these issues. In the following I will focus on the question which support is needed for the development of endogenous farming patterns, particularly those related to irrigation.

Box 7.1 Some obstacles to endogenous development

It can be foreseen that a reorientation of policy in the direction of endogenous development and the realisation of endogenous development potential is not easy but problematic for many reasons. The main reason is the lack of trust between the rural population and the State. This has historical roots, profoundly sedimented in the collective memory of the rural population. The 50 years of Fascism and corporatism before the 1974 Carnation revolution constituted a history of oppression and negligence. The state was at the same time omnipresent and 'omniabsent', in the words of Portela (1988). On the one hand, the State imposed taxes and regulations, controlled the markets, made emigration difficult, imposed military service (many men have been drafted to fight in the colonial wars in Angola, Mozambique and Guinea-Bissau), imposed afforestation of the commons etc. On the other hand the State hardly did anything to satisfy the basic needs of local people (education, health, social services etc) and to support the development of the region. The rural population itself had to create its own basic infrastructures, to create its own employment, to develop its own knowledge and to rely on the knowledge of its ancestors regarding health, nutrition, agriculture etc. The relations between the State and local society could be classified as an unequal confrontation. The rural population had responded with its own weapons political manipulation and administrative control of the State: subtitle resistance, legal and clandestine emigration, retention and manipulation of information, fraud, withdrawing from markets (Portela 1993:10).

Apart from these deep historical roots, the contents, character and style of actual state policy and intervention do not instil much credence in the rural populations. A very important point is the subsidy culture which has dominated since the late 1980s the agricultural policies on a national and regional scale. With the entry of Portugal into the EEC much financial means came available for the development of Portuguese agriculture.

A proliferation of a variegated array of subsidies with the associated bureaucracy took place in Portuguese agriculture. They have profound and contradictory influences in the agricultural sector. First, the subsidies associated with product price support and income subsidies for farmers of disfavoured areas (nearly the whole of Portugal) according to cultivated area and number of cattle (*indemnizações compensatórias*), set-aside and extensivation regulations are a necessary support for low farming incomes.

Second, Portela shows in an impressive essay (1999) that the actual subsidy policy and practice shaped by the Portuguese State (but forming part of a broader policy linked to Portugal's membership of the EU), are highly demotivating for farmers and their successors to stay in the profession. 'Planting, receiving subsidies but not harvesting' or 'harvesting here and burying it there' in a country which still has to import a great deal of its food necessities is felt as an absurdity opposed to the cultural repertoire of most (small) farmers.

Third, the distribution of subsidies is highly skewed. Until 1996, about 57 per cent of the different funds have been applied in the southern areas of Alentejo and Ribatejo e Oeste (Larcher Graça 1998) where a minority of the farming population lives. Principally the access to EC investment grants is highly selective. These '797' projects are aimed at the creation of 'viable' agricultural enterprises and strongly biased to large farmers and 'promising' regions.

Also in Trás-os-Montes subsidies for farm development are concentrated on a relatively small segment of the farmers' population. Oostindie *et al.* (1995) stress the strategic coalition between regional agricultural technicians and a relatively small group of farmers. This strategic coalition is very much interlinked with the allocation of '797' funds. Regional technicians elaborate investment plans for a selected group of farmers. According to most farmers these technicians not only charge a high percentage of the total investment fund , they also show very little interest in smaller investment plans. Most farmers are interested in small, specific investments which in their perspective could remove specific bottlenecks and create favorable conditions for continuity. However, investments as part of a complete package, fitting into an externally defined farming model which supposes the transformation of all aspects of farming, are favoured. Regional technicians, in turn, confirm the access as a principle

reason for the selectivity of the '797' investment fund. They justify their percentages in terms of the time-consuming bureaucratic obligations associated with this funding.
Whatever the reason, only a very limited group of farm households have succeeded in taking advantage of the EU grants. The overall impact of the investment programs, however, is far more important than this limited access would suggest. Access to the '797' grants is often an important factor in the decision of farm households to continue farming. *No access to EU funding for farm investments is often perceived as a label of 'no agricultural future'*. In other words, this provides another motive for leaving the region and abandoning farming. Therefore, it could be seriously questioned whether the overall impact of the way EU funding is implemented does not enforce rather than counterbalance the marginalisation process (Cristóvão *et al.* 1994)

The selectivity of the relations between the State and the farming population is also shown by the introduction of the dairy quota system in the early 1990s. Whilst the intensive dairy farmers were given the opportunity to increase their dairy production, the quota of the SCOM farmers was determined on the basis of their average production in recent years. In this way their chances for developing their dairy production further was severely limited (Oostindie *et al.* 1995:65).
Many other examples could be given but they are outside the scope of this thesis. In this respect, I would like to refer to the contribution by Portela (1994) to the White Book dealing with the future of Portuguese agriculture.

A last obstacle is related to the political culture and the style of intervention of State agencies. The political culture cannot be seen in isolation from the history and the relatively recent democratisation of Portuguese society. Farmers relations with agricultural institutions and state agents are complicated and can best be characterised in terms of distancing instead of negotiation and collaboration. The attitudes of farmers and state agents mutually reinforce each other. This distancing is clearly expressed in the two culturally deeply rooted metaphors of *Senhor Engenheiro* and *cunha*. The large social distance between the farmer population and state agents and technicians is reflected in the inflated use of the title *Senhor Engenheiro* (*Engenheiro*, literally engineer, is the official title for graduates of technical universities at BSc or MSc level). Most farmers demonstrate or simulate in direct contacts a highly respectful attitude towards technicians. They do not oppose the opinion of '*Senhor Engenheiro*' or as they say '*dança-se conforme a música*' (one dances according to the music). If a technician informs them that it is impossible to get a grant for a certain investment plan, there is no other alternative than to find another one. That reflects the importance of the other metaphor, *cunha* (literally wedge or connections) which means that one needs to have personal contacts within the institutions allowing one 'to wedge one's way into the government body' (Oostindie *et al.* 1993:181). It will be clear that the *cunha* is of particular importance when government departments function inadequately. The appearance of '797' investment subsidies offered technicians important new opportunities in relation to the *cunha* phenomenon. The bureaucratic obligations and the economic calculations about the viability of the investment plans make the support of technicians in the elaboration of investment plans indispensable.
In short, although Portugal might be in a process of democratisation, according to a lot of farmers little has been changed compared to the times when state corporatist bodies like the *casa do povo* (literally 'the people's house') and *grémios* (literally 'guild') were strongly dominated by the local 'noblige' and clerics (Oostindie *et al.* 1993:182).

In endogenous development, farmers' associations, cooperatives and other local groups represent the human resource potential. Endogenous development requires the predominance of local actors, local democratic decision-making, local control of resources and the sharing of local benefits. An example of such a local organisation is the association of Barrosã breeders, created in 1988 with the objective to define and implement strategies to preserve this local breed and to add extra value to meat production. This association, as a clear example of endogenous initiatives, needs to be supported and strengthened by means of development of the local capacity of representation and negotiation with the exterior, organisation building, training and networking on different levels (Christóvão *et al.* 1994:55). At the same time such support and processes require new styles of intervention (facilitation instead of prescription) from state agencies and agents, trained and socialised under the modernisation framework, devaluing local resources and local knowledge and frequently characterised by sectoral, technocratic and bureaucratic visions. It requires in particular the development of a new vision and attitudes in which prescription is substituted by departing from and building on existing resources and the situation as it is and developing the potentialities harboured in these resources and that situation.

The question of the most appropriate way to strengthen the development of endogenous farming patterns is highly complex with many interrelated aspects[8]. Local resources and practices (e.g. *baldios* and FMIS) are only useful when they are embedded in particular farming styles that reproduce these resources. Their use and reproduction need to be valorised by markets. The latter condition implies the specification of local products (e.g. *Barrosã* meat) and of specific food circuits that allow for the required commercialisation and valorisation. If such is the case, then specific benefits will result that might satisfy the interests of the involved 'social carriers'. On the other hand, such a social carrier (a specific group of interested and involved actors) is needed to maintain the required farming styles. All the above mentioned elements are local resources. But only through the creation of the indicated interrelations, an effective process of endogenous development could develop (van der Ploeg *et al.* 1995a). *Local practices and resources, production chains, social carriers and the social organisation have to be brought 'in line'.*

One of the most problematic points of the endogenous development path of quality beef production is the whole complex related to the development of production and commercialisation circuits of the *Barrosã* cattle[9] (Tibério 1994). Second, an increase of scale (labour objects per labour unit) requires specific labour-saving technology. Moreover, the further development of this farming pattern requires a new attention to the management of the *baldios* and *lameiros*.

A crucial problem of Trás-os-Montes' agriculture is the scarcity of labour. Farmers are adapting their farming to this condition. This manifests itself in very different and sometimes contradictory ways but the extensification of land use, the conversion of arable land in *lameiros* and the abandonment of marginal plots are general features. Some specific support programmes which are offering alternative land uses responding to the scarcity of labour are very successful. Farmers respond massively to these programs and demand their extension. Examples are the planting of chestnut trees and afforestation of private farm land (Baptista 1999).

A crucial support to increasing scale and labour productivity would be the design and development of a proper supply of technology adapted to local conditions (topography, steep slopes, difficult access, small plots etc).

A great scope of activities is possible to increase labour productivity in farming activities on small farms by the development and introduction of appropriate farm mechanisation: in the production and processing of hay[10], the production and application of manure[11] (E. Portela 1994; E. Portela *et al.* 1994) etc.

Also in irrigation, it is possible to design and to develop technology aiming at reducing labour input, as will be shown in Chapter 7.3.

Appropriate irrigation interventions

The two contrasting farm development patterns have different implications for irrigation interventions. It is shown in Chapter 5 that incomes in the endogenous pattern of the 'intensifiers' depend only for a small extent on scarce summer water. The *baldios* (pasturing) and *lameiros* (hay and pasturing) are the basic fodder resources. Fodder produced with scarce summer water (green maize, turnip, fresh grass) is additional and not essential. The most important role of summer irrigation in the endogenous pattern is the production for household consumption.

The development of the exogenous pattern, however, is very much dependent on increases in scarce summer water and as this required water is hardly available, the development of this pattern is hampered in the natural and socio-economic context of Trás-os-Montes. This pattern implies high transformation costs such as the construction of dams and associated artificial lakes.

In conclusion, given a limited state budget for support to agrarian development, a higher impact can be achieved by developing endogenous farming patterns through suitable interventions (irrigation and other) than by developing exogenous farming patterns.

In terms of the desired irrigation development, as far as the endogenous farming pattern of the 'intensifiers' is concerned, it is neither necessary nor desirable to make huge investments in water resource development by constructing dams aimed at the creation of considerable quantities of extra summer water. In addition, it would be potentially dangerous to support the development of individual sources of water because -instead of creating 'new' water- this could stimulate the redistribution of available water resources and the undermining of existent FMIS.

This is not to say that there is no room for considerable support, also in terms of irrigation interventions, but this has to be built on the potential harboured in endogenous farming patterns and emerged problems as a consequence of changes in the rural context. To develop the endogenous pattern of quality meat production, two specific support actions in the sphere of irrigation seem to me particularly important. These support actions, which are primarily aimed at increasing scale or labour productivity, will be discussed below.

** Expansion and intensification of irrigated lameiros*
Lameiros and *baldios* are the basis of the fodder production in the endogenous farming pattern of the 'intensifiers'. The hay production of the *lameiros* (for consumption in the winter) is normally the most important limiting factor for the number of cattle a farm can hold. The irrigation of hay meadows is the most important irrigation practice in terms of area representing two thirds of the total irrigated area in the mountains (see Table 2.3). It is also the only practice that makes the water in autumn, winter and spring productive.

Over time, some *lameiros* have seen more extensive use (e.g. only for pasturing) than before or even abandonment, and vice versa. These shifts are principally caused by the scarcity of labour and the unsuitability of plots for mechanical harvesting. Drainage conditions, access, steepness etc (see Box 2.6) are determinant factors in these shifts.

A relevant question is the *possibilities of expansion* of the *lameiro* area and the *intensification* of its production in the mountainous zones of Trás-os-Montes. In principle there are two ways to expand the area of irrigated *lameiros* and to intensify its production.

First, the removal of (some) obstacles mentioned before constitutes a potential for expansion and/or intensification (improvement), for instance, by draining very wet plots both allowing mechanical harvesting and increasing hay yield (improving floristic composition).

Second, it is known that in the Mountains and the High Valleys there is no lack of water in the winter and spring periods. At the same time, access to water in these periods is generally not limited by rigid defined water rights like in summer. That basically constitutes a potential for expansion that could be explored. But these are very general statements. There will be considerable variation in time and space dependent on rainfall patterns, topographic conditions and the importance of the *lameiros* in local farming. All the foregoing points to considerable lacunae in knowledge.

On the other hand, Gonçalvez (1985) makes it clear that the irrigation of meadows in winter is a complex issue. An interplay of various factors and conditions (type of water source, quantity of water, meteorological conditions, exposure of the meadow to sunlight, the location of the meadow and the distance to the water source, timing of irrigation) determines the success, efficiency or failure of this practice. Various contradictory statements and facts about the nature of the *rega de lima* exist e.g.

- Regarding physical factors, it is difficult to understand why in the Mountains areas this irrigation practice is far more important than in the High Valleys. In some parts of the High Valleys there occur more frost days (e.g. Pedras Salgadas, see INMG 1991) than in the Mountain areas.
- Some farmers say that for the *rega de lima* you need relatively warm water from springs that give relatively small discharges compared to river flows. In contradiction to this statement is the opinion that you need large water quantities, and that without them it is better not to irrigate at all. On the other hand, the use of river water would be only beneficial from the end of the winter months (February-March) on.

This suggests that the underlying ecological and local factors which explain the nature and importance of the *rega de lima* are not well understood. Research on this irrigation practice might yield useful insights for improvements and expansion of *lameiro* irrigation. Such applied research undertaken by a team of researchers from different disciplines will, in my opinion, constitute an outstanding example of institutional support to regional agricultural development.

** Revitalisation of Farmer-managed irrigation*

In contrast to the exogenous farming patterns, the demands that the development of the endogenous farming patterns pose on irrigation can be realised within the framework of the existing physical and social irrigation infrastructure. However, the way traditional irrigation systems and practices function needs to be revitalised. These systems and practices have been created over long periods of time by local actors according to their interests and conditions. However, local society, agriculture and the environment in which the irrigation systems are embedded have changed drastically over the last decades. The most drastic change affecting rural society and agriculture in recent years is and continues to be an overwhelming scarcity of labour. In particular, labour scarcity clashes with the labour-intensive and arduous nature of traditional irrigation practices.

Adequate improvement plans for traditional irrigation systems must focus on lowering the amount of labour and the drudgery involved in irrigation activities. The amount of labour time saved in this way could be used for other farming activities (a scale-increasing potential).

The MRT intervention is an important step in the direction of a meaningful improvement in traditional irrigation systems. But the impact of the MRT intervention is limited by the nature of MRT itself. MRT interventions have been confined to a standard repertoire of technical measures to limit water losses. However, it will be relevant to examine if there is room for improving the functioning of the traditional systems in the sense that they are better adapted to a changing context and changing farmer’s goals, resources and conditions. Broadening the scope of MRT technical measures in this way signifies a step forward compared to actual MRT interventions. This broadened MRT intervention, focused on realising local development potential, could have more impact than the actual interventions. Strategies to improve actual interventions are discussed in Section 7.2. The improvement of the actual irrigation systems and the further development of the actual skill-oriented irrigation practice, particularly its labour-saving potential and its translation into technical measures and management changes will be elaborated in Section 7.3 and 7.4.

Conclusions

It can be concluded that in terms of *potential impact*, the endogenous farming pattern based on the sustainable use of natural resources is the most adequate development pattern in the mountainous areas of Trás-os-Montes, particularly in Barroso. Extrapolated to a regional level, endogenous development produces a higher value added and more employment opportunities. Also the preservation of typical landscape values and the natural environment is guaranteed by this development pattern. However, it means that in policy, a shift from support for exogenous development to endogenous development is necessary. In particular, irrigation interventions need to be reoriented to support endogenous development.

7.2 From MRT to an alternative approach to strengthening local development

Trás-os-Montes is a so-called marginal region whose rural areas are seriously threatened by human depopulation. To arrest this tendency, rural development in Trás-os-Montes is of the utmost importance. The implementation of exogenous development blueprints from the European growth poles is not recommendable because of the negative economic and environmental side effects. Moreover these external development models are virtually impossible to implement because of the prevailing physical and socio-economic conditions in Trás-os-Montes. So, an alternative must be sought in the development of the local potential of human and natural resources and infrastructures.

Departing from that premise, the efficient exploitation of water resources is of great importance for sustaining and developing Trás-os-Montes' agriculture. However, to reach this objective various *alternatives* exist to improve actual irrigation systems. The choice between alternatives should be carefully made on the basis of understanding the functioning of existing irrigation systems and the recognition of farmers' own development efforts. Taking this as a basis, external agents may play an important role in strengthening local development. Although actual state interventions in FMIS respect the local situation, they are limited and do not take in account the diversity in functioning and the local dynamics found in the farmer-managed irrigation sector.

Based on the diversity and local dynamics found, the following *intervention strategies* - concerning both the content and the process of intervention- are vital for improving the actual interventions in FMIS:

* An *integrated approach* to local (irrigation) development. The actual public interventions in FMIS are often isolated actions and not systematically linked to local development, specific needs and priorities (see Chapter 6). The same is valid for other interventions by other (public) agencies; they are often ill-adjusted to the local situation and coordinated from a local perspective. Priorities for local development may envisage that irrigation development, to be effective, needs to be complemented by other interventions.

* A crucial point is the role of irrigation in farming and their complex interactions. Irrigation practices cannot be understood as isolated phenomena but are integral parts of farming. Key questions are: what is the role of irrigation in specific agricultural practices of specific (groups of) actors (e.g. 'modernisers', 'intensifiers', SCOM farmers, pluriactives, old farmers, women etc.)? What kind of irrigation improvements would create a condition and/or a stimulus for local agricultural development patterns?

* Concerning irrigation development, a whole *range of interventions* need to be considered from a local perspective, and not only the actual uniform type of intervention, that is the improvement of the physical infrastructure of the supposedly most important

communal system of a village. As I have already indicated in section 2.5, interventions by water users are much more diverse, context dependent and space/time specific. Moreover there are linkages between different factors, e.g. an increase of water availability will (again) spark off local discussion about water allocation and distribution, i.e if the actual distribution pattern will fit the new situation created by the intervention. A repertoire of possible technical and management interventions and their linkages will be presented in Chapter 7.4.

* An integrated approach implies that intervention needs to be considered in *all aspects and effects* which are not necessarily limited to one system or one village. Adequate interventions need to consider a whole catchment area in cases where various irrigation systems depend on the same surface water resource or even to a whole region where groundwater development is taking place. To assess the reasons for canal lining, the whole local context need to be taken in account. In Chapter 6 it was already shown that the MRT intervention cannot be considered a purely technical neutral intervention. In many situations lining, permanent weirs and individual water sources development (stimulated by investment subsidies) mainly result in redistributive effects, not in more irrigation water at the village or intervillage level. This clearly shows the importance of the design principle of clearly defined boundaries (see Box 1.1), not only in the physical sense but primarily social, that is the locally defined rights to use water from different sources. Intervention could affect the realisation of these rights.

* A more elaborated *inventory* and *diagnosis* are primary conditions to improve actual interventions. Until now, the inventory of FMIS was limited to technical constraints. Moreover, it was based on information of a limited number of local informants. Improved inventory needs to include actual functioning and dynamics of FMIS, specific local needs and local initiatives in order to prevent external proposals being inappropriate to local realities. This requires an exhaustive consultation of different actors at the local level. Essential information needs to be collected on:

- the relative importance of and the specific balance between communal, groups and individual irrigation facilities at village level.
- the relative importance of winter and summer irrigation.
- the key determinants of heterogeneity in functioning of FMIS (water allocation and distribution) and the related rigidity and flexibility of water use at the farm level.
- the balance of water availability (implying measurement of source flows in time) versus water needs, taking in account the local farming systems.
- local dynamics as expressed by farmers interventions, ideas and discussions but also in a indirect way, e.g. requests for support to state agencies.
- limiting factors such as e.g. labour scarcity

Selection criteria for intervention can be derived or established leading to the next intervention strategy.

* Improved *selection* and *prioritisation* of sites considered for intervention. The selection of irrigation systems to be improved was based on mostly technical criteria (access paths, length of main canal, size of weirs, water flows, size of irrigated area, quality of soils, size of village population), economic criteria (cost ceiling[12]) and biased

towards quick implementation. Instead, selection criteria should be related to development perspectives and local dynamics. Examples of these selection criteria could be the intensity and orientation of production and the percentage of full time farmers as part of the village population.

* Defining the decision-making process as a *joint venture* of government bodies and local water users. To date, water users hardly have been involved in the planning and design phases of the intervention. The content (what to do) and process (who, how, when, where) of intervention needs to be defined and discussed at the local level by all actors who take an interest in the intervention. The content and process of intervention need to be explicit issues in the decision-making. In doing so, intervention may present a suitable opportunity for organising debate, establishing new rules which permit gaining the greatest and most equitable local benefits from the envisaged intervention.

* Defining intervention as supporting ongoing local dynamics and strengthening local initiatives, furnishing resources which are outside the reach of local actors. This implies the creation of a new relation between local initiatives and public-sector efforts which, in practical terms, signifies an important rupture with usual interventions. The actual government interventions are not linked to local initiatives.

The fact that farmers (communities), in many cases supported by local (state) organisations (*Junta de Freguesia, Comissão de Baldios, Conselho Municipal* etc) themselves actively intervene in irrigation development is of crucial importance. It is an indicator of the capacity of water users and their organisations to create and change things. It represents a potential that is actually not used and developed by external interventions as MRT. This potential of local initiatives can be combined with the external efforts to improve irrigation systems through an approach similar to what Coward called '*the indirect investment approach*'. Through indirect investment, critical resources (e.g. materials, equipment, technical assistance) are provided by State agencies to local irrigation groups to create and improve those locally owned and managed systems (Coward 1986). External assistance has a *complementary* character and must be tailored to match the local needs in each system. I consider this intervention strategy to be one of the most important because it has the potential to expand rapidly the gradual improvement of the systems according to local needs. Moreover, this practice has some tradition in Trás-os-Montes. For instance, in the hamlet of Sobradela some works undertaken by the *Junta de Freguesia* (materials supplied by the JF, labour provided by the water users) have improved considerably the two local communal systems (Bleumink *et al.* 1992). The water users of the most important FMIS in Alvarelhos have partially lined their canal with support from the municipality of Valpaços which supplied construction materials and made available a retro-excavator (Pinto Marques *et al.* 1995:21). These are no exceptions; many examples of local initiatives and the combination of users' resources (principally labour) and local (State) organisations (supplying materials etc) could be given[13]. If the groups of water users, who ultimately are the risk-takers of irrigation investments, are given due status they can make themselves accountable before institutions which supply these resources.

* Because farmers take a *risk-avoiding attitude*, improvement might well succeed on limited scale. This links up with the way farmers intervene in their systems, that is partial

improvements, step by step. This strategy is closely related to the ‘indirect investment’ approach and signifies a rupture with actual implementation of improvement actions. It implies that the role of external agents as constructors will be of another nature, for instance the construction of specific parts which are outside the reach of the local community.

* Building upon farmers’ *local knowledge* about the area, physical conditions and related irrigation practices. Farmers’ knowledge of specific local farming and related irrigation practices is of crucial importance in order to create adequate designs adjusted to these practices. In actual MRT interventions, farmer consultation is minimal. Using local knowledge will point to solutions (adequacy, cost-effectiveness) that are better suited to specific local problems, e.g. the selective lining of canals where is it most necessary. A concrete example is the partial lining of the main canal of the FMIS in Alvarelhos. The parts to be lined have been chosen by the farmers. From two canal stretches of 100 and 111 m respectively, 66 and 32 m respectively were lined before the summer period started in 1994. Measurements of losses in 1993 (before lining) and 1994 (after lining) showed that in the first part canal losses diminished from about 12 per cent to 0 per cent and in the second part canal losses diminished from about 55 per cent to 15 per cent (Pinto Marques *et al.* 1995: 21, 22). Moreover, *selective lining could be more efficient*, that is total canal losses might decrease more with the same costs if only crucial parts of the whole irrigation infrastructure in a village would be lined instead of one canal being lined completely. In this way, the benefits of these government subsidies could also be divided more equally over all the households within a village.

In summary, irrigation development does occur as a result of both individual and collective farmer's initiatives, but external agents may also play an important role in strengthening irrigated farming. State interventions tend to take on an uniform character and neglect local diversity and dynamics. So, heterogeneous farmers' demand is not matched by a homogeneous state supply. In order to avoid this obstacle to local development, joint ventures between farmers and external state agents are required. This, of course, presupposes strong and dynamic local organisations.

7.3 The redesign of the ‘Vila Cova’ farmer-managed irrigation system

In this section I will present and discuss the redesign of the communal irrigation system of Vila Cova. The central question is which design of the technical infrastructure and the functioning of farmer-managed irrigation constitute an improvement in relation to the actual situation and the conventional MRT design. From this central problematic more questions follow: *What are the possibilities to build upon ‘traditional’ practices, developing them further and adjusting them to changing conditions? How could these possibilities be translated into interrelated changes in irrigation infrastructure and management of the systems?* I will start from the actual functioning of the system as described in Chapter 3.2, the local context in which irrigation takes place and the most important problems mentioned by the water users.

The MRT intervention in the Communal Irrigation System of Vila Cova

In 1986 an MRT intervention had taken place in the communal irrigation system of Vila Cova (GAT 1985). Basically, the intervention consisted of the construction of a permanent diversion weir and the lining of the upstream parts of the primary irrigation channels[14] (700 m or 20 per cent of the total length of the primary channel network). This limited intervention reduced real water losses and resulted in various positive effects. The lining of the canals increased irrigation flows, reduced travel times and extended the period that irrigation water arrived at the downstream plots from mid-July (before the MRT intervention) until mid-August for the downstream plots. The reduced travel times permitted a higher number of water exchanges between plots without diminishing the effective field irrigation time (Carvalho 1994).

Nevertheless, I think it is possible to take some steps further in the improvement of this system and which respond more adequately to various problems experienced by the water users.

Problems that affect the irrigation system of Vila Cova

In Vila Cova water users mention as the most important problems of their communal irrigation system that affect irrigation practice: *night irrigation, the complexity of water distribution, the tail end of the 'veiga' area receives hardly water and the high labour requirements in irrigation activities*. These problems are related to the changing context in which farming and irrigation take place. Principal determinants of these changing conditions are the ageing of the population, the scarcity of labour and the increasing pluriactivity of the households. They affected the suitability of the existent irrigation systems and practices during the last decades. In the first place it must be noted that on an individual level farmers have already 'discovered' ways to cope partially with these problems e.g. by means of water exchange in which night water is applied on meadows, construction of plot reservoirs, exploration of individual water sources etc. In the following an attempt will be made to go beyond these individual solutions and to propose concrete technical measures and changes in the functioning of the collective irrigation system in order to (partially) solve these interrelated problems. I will start from the way the actual system is working.

Night reservoir and its design

Irrigation water in the Vila Cova system is now flowing permanently, i.e. 24 hours per day. Night irrigation at system level could be eliminated by the construction of a night reservoir, located at the head end of the system near the diversion weir in the river (see Figure 3.4). But eliminating night irrigation has profound implications for the actual water distribution practices and rules. A decisive question emerges, namely if the actual water distribution pattern and the underlying water allocation may be *compatible* with the elimination of night irrigation. In other words, if the new water distribution pattern as a result of night storage could have approximately the same outcome than the actual water distribution based on the existing water allocation schedule. In the following analysis I will examine this question.

The required *capacity of a night reservoir* is determined by the size of the incoming flow and the length of the night period. The size of the incoming flow is dependent on the period of the year that the reservoir will be used for night storage. In the actual situation night irrigation only becomes important in the period that water is scarce which coincides with the period that the summer allocation schedule is implemented, i.e. from about the end of June till about the end of September. Outside this period there is hardly any need to use the reservoir for night storage. When there is need for water for the *lameiros* and summer crops planted or sown earlier in the *veiga*, water will be allocated according to the *a vez* rule. Outside the summer period, the envisaged reservoir could be used to accumulate water or it could pass the reservoir continually or even bypass the reservoir.

Let me define the *length of the night period* in the summer period as 8 hours[15]. The water of these 8 hours then needs to be stored in the reservoir. Then naturally the question of the actual *canal dimensions* pops up. The night storage of 8 horas signifies that the irrigation channels need to convey higher flows, on average (24/16)-1=50% more than the actual summer flows. The transport capacity of the irrigation canals is not known but because they also function in periods in which source flows are higher than in the summer period, I will assume that within certain limits there is enough room to accomodate the increase of flows caused by the reservoir.

In the summer period, *source flows* have been measured from 10 l/s up to 20 l/s[16] (Carvalho 1994). How to deal with this varibility of source flows I will come back later on. But with an assumed maximum flow of 20 l/s the reservoir needs to have a total 'useful' capacity of 8*3600*0.020=576 m3.

Then it is necessary to analyse two questions. First, what is the desired *outflow pattern* of the reservoir during the day? Second, how can this desired outflow pattern be achieved with minimal *operational requirements* representing maximal transparency and minimal management or transaction costs? Regarding this last question, the optimal solution of course will be no regulation of the outflow valve except for the unavoidable opening and closing of the reservoir at the beginning and the end of the day (on-off valve).

When the reservoir is full early in the morning and will be opened, the flow of the water in the channels is at its maximum and needs to decrease during the day to source flow at the end of the day. The reservoir and the outflow opening need, then, to be dimensioned in such a way that the stored water during the night is gradually released in 16 day hours. In an irrigation turn, the users at the upstream end, assuming irrigation running upstream to downstream, receive a much higher flow than the users at the downstream end. Although, this can be compensated for irrigating downstream to upstream in the next turn.

However, a *crucial question* emerges, that is, what are the effects of this compensation on the distributed water over the plots? Will the result of the two turns result in a distribution of water over the plots which is approximating or equal to the result of the actual water distribution? This comes down to the technical question to examine the variation of the resultant flow i.e. the sum of the flows of these two turns over the irrigated plots along the channel. If the variation of this resultant flow is zero or minimal then the distributed water to the plots will be equal to or approximate closely the distributed water to the plots according to the actual 24-hour water distribution. This can be best achieved if the outflow from the reservoir decreases linearly as a function of time, during the day. This is visualised in Figure 7.1.

However, following this reasoning, the question under which technical conditions this desired linear decrease will take place is decisive. Therefore, I have first analysed the outflow during the day of a night reservoir as a function of time with a *permanent inflow*, i.e. when all the source flow will continuously enter and pass through the reservoir. In Appendix IV the respective outflow pattern is derived. This did not result in the desired linear decrease of outflow as a function of time as is shown in Figure 7.2. This specific outflow pattern corresponds to the calculated reservoir and outlet orifice dimensions outlined in the arithmetic example in Appendix IV

Figure 7.1 Water distribution Casal X (waterusers a-z)
Comparison Permanent flow vs. desired flow pattern night reservoir

linea

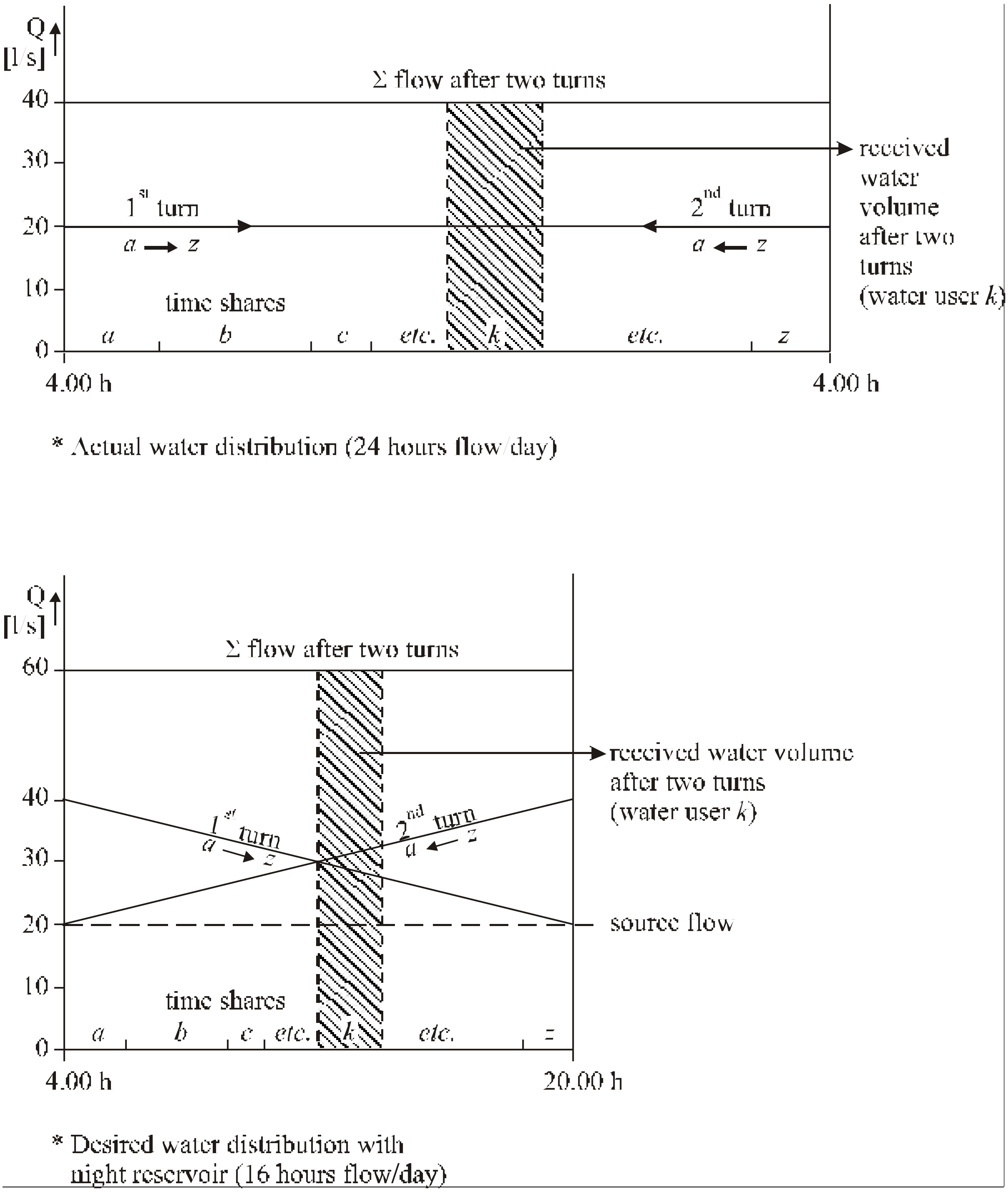


Figure 7.2 Resulting Outflow Pattern from a Reservoir with Permanent Inflow after Two Irrigation Turns

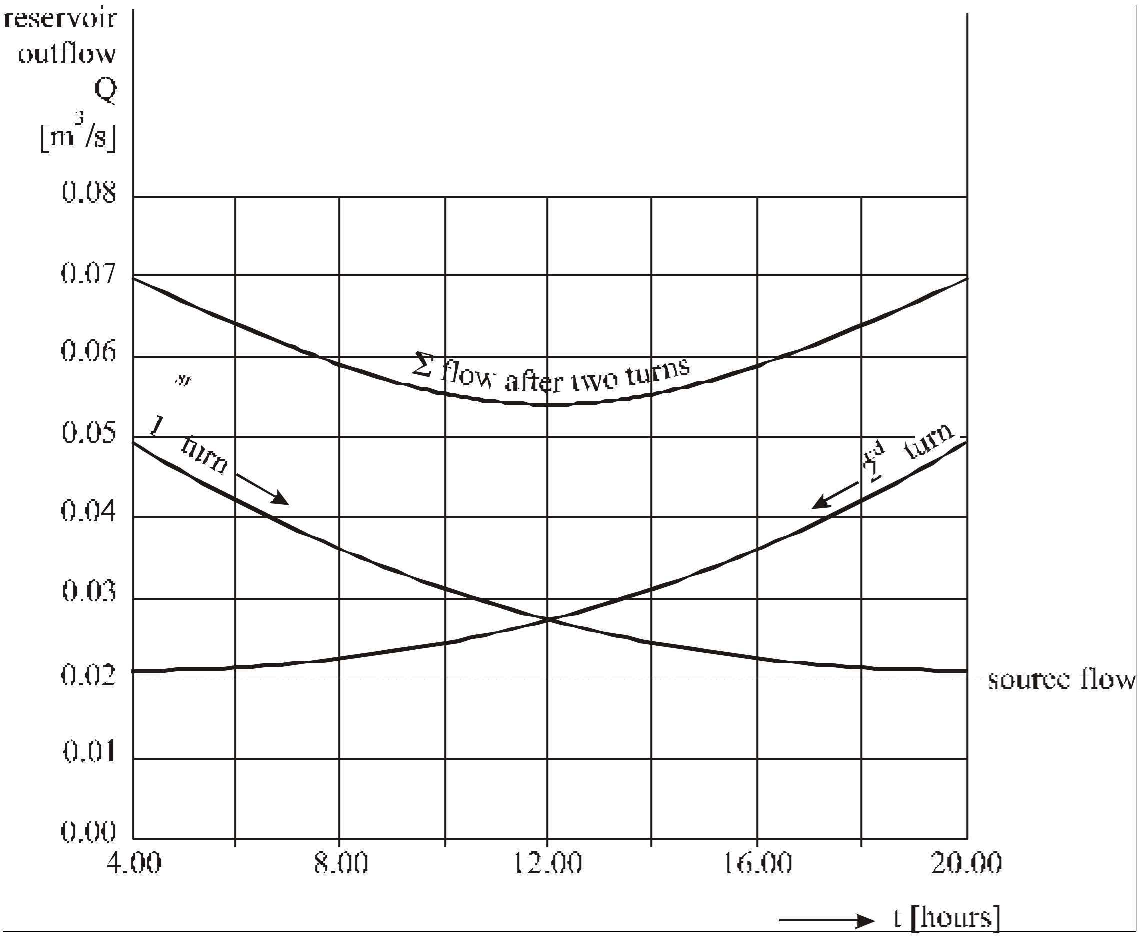
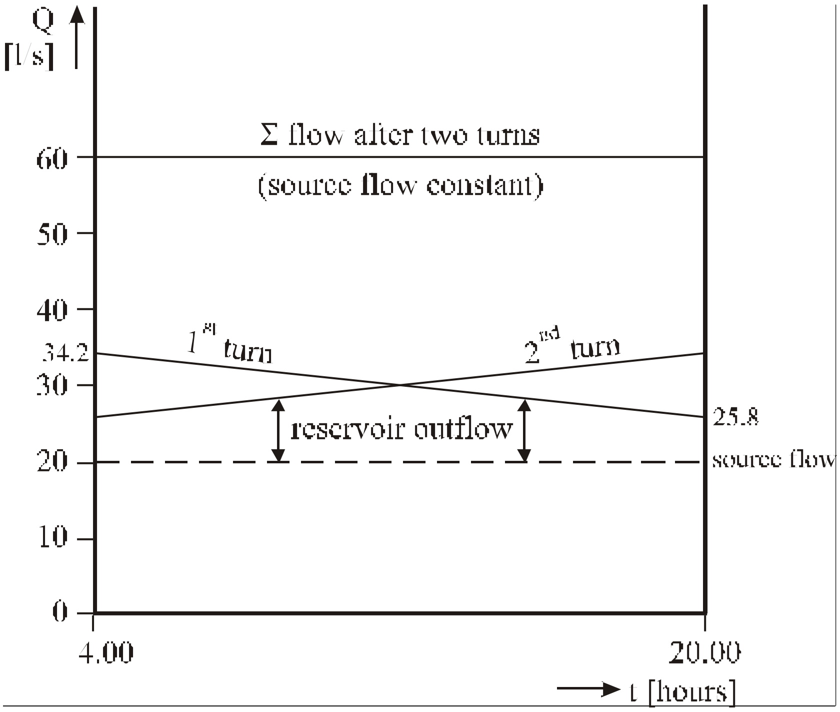


Figure 7.2 shows that the water users in the middle reach of the canal (receiving water in the middle of the outflow period) will receive receive in two turns (first turn: upstream→ downstream; second turn: downstream → upstream), in comparison with their original water rights, systematically less water than the users in the upstream and downstream reaches of the canal. This situation cannot be easily remedied, it will require more complex compensatory mechanisms than the actual ones. It will lead to water 'jumps' and more canal losses. This option is also problematic because of two additional questions. First, will the high outflows at the start of the day (approximately 50 l/s, i.e. 2.5 times more than the source flow in the example) fit within the existing irrigation canals? Second, will these high initial flows be suitable for the water users taking in account the existing organisation and methods of field irrigation? These are questions which need further study to assess in which degree the operation of a reservoir with a permanent inflow is compatible with the actual water distribution and plot application.

Whatever the answers, it can be concluded that a reservoir with a permanent inflow is a problematic option: its outflow pattern is hardly compatible with the actual water allocation and distribution.

Then I studied another outflow option: the outflow from a reservoir in which the source flow will bypass the reservoir and flow directly to the canal during the time. At the same time the night water is flowing out of the reservoir. In Appendix V the correspondent outflow pattern is derived. This resulted in the desired linear decrease of outflow as a function of time, as shown in Figure 7.3

Figure 7.3 Resulting outflow pattern from a reservoir with no inflow during the day period after two irrigation turns



This *specific linear outflow pattern* corresponds to the calculated reservoir and outlet orifice dimensions outlined in the arithmetic example in Appendix V. The canal flow is the sum of the linear decreasing reservoir outflow and the constant source flow. An advantage of this option is that the canal flow at the start of the day is smaller than with a reservoir with a permanent inflow (compare Figure 7.2 and Figure 7.3). Also the *outflow variation* can be hold within certain limits depending on the choice of the design parameters. Sensitivity analysis also shows that the outflow variation is minimally affected by any deviations of the assumed value of the orifice discharge coefficient (see Appendix V)

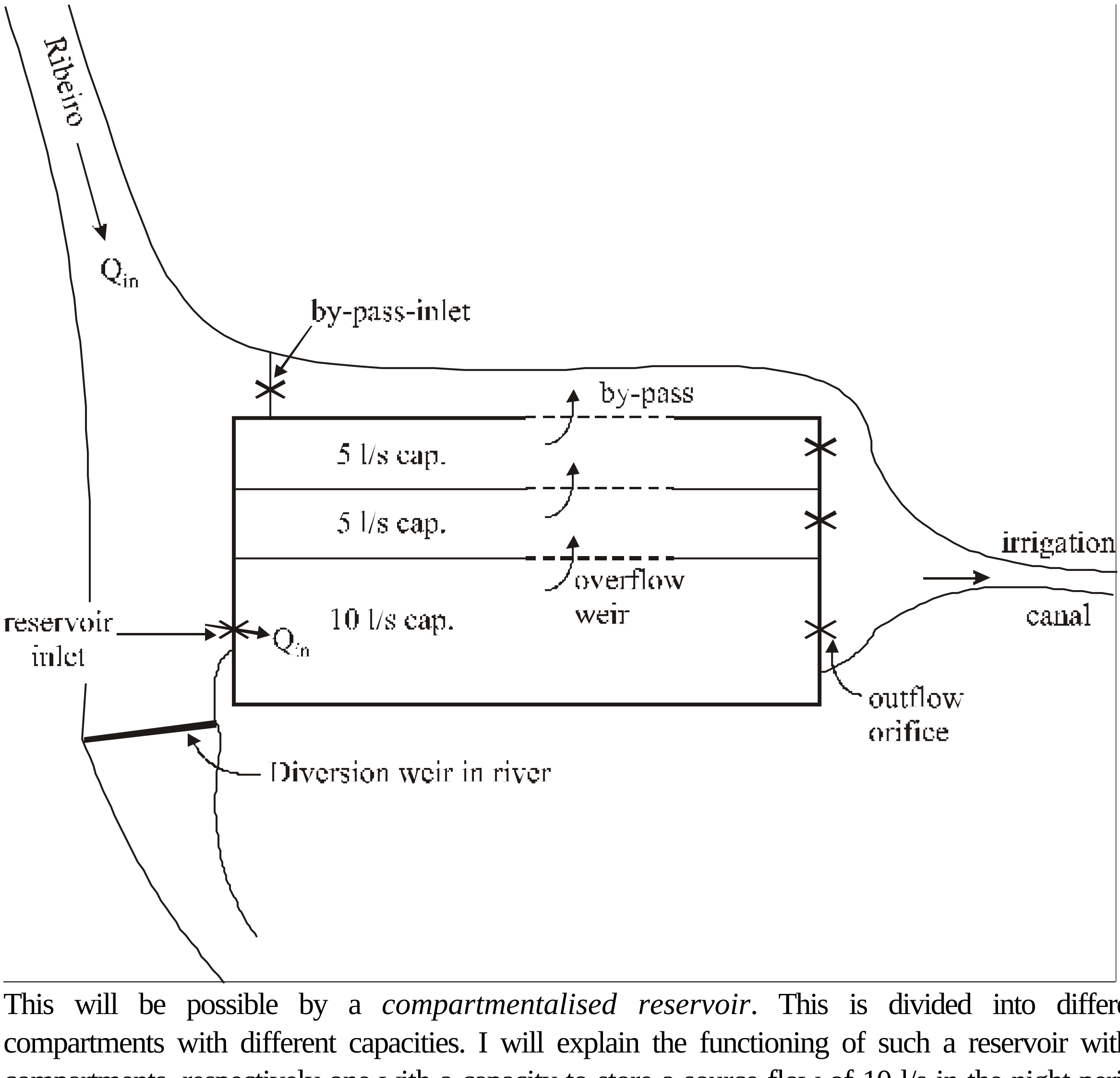
Moreover the *operational requirements* of this solution are minimal. Operational activities are necessary at the start of the day (opening of the outflow orifice(s) of the night reservoir and the bypass from the source to the channel, while at the same time closing the inlet of the reservoir) and at the end of the day (closing of the outflow orifice(s) reservoir and the bypass, while simultaneously opening the inlet of the reservoir). During the day no further adaptation of the streamflow by manipulation of the outlet valve(s) of the reservoir is necessary.

To complete the design of the night reservoir the *variability of the source flow* during the summer must be taken in account. This question is discussed in Box 7.2. It can be concluded that the night reservoir can be designed in a way such that it provides an approximately linear decreasing outflow over the plots which will be irrigated during the day for varying sizes of the source flow within the range that is normal in summer.

Box 7.2 Accounting for the Variability of the source flow in the Design of the Night Reservoir

In a 'dry' year (1992) a range of source flows is measured between 10 l/s and 20 l/s in the summer months. In the design of the reservoir, this variability has to be taken in account. The question is how to do this under the condition of a linear decrease of the reservoir outflow and without increasing operational requirements.

The functioning of a compartmentalised night reservoir



This will be possible by a *compartmentalised reservoir*. This is divided into different compartments with different capacities. I will explain the functioning of such a reservoir with 3 compartments, respectively one with a capacity to store a source flow of 10 l/s in the night period and two additional ones, each with a capacity to store a source flow of 5 l/s. It functions as follows (see the Figure below): the flow enters first to the 10 l/s capacity compartment. This compartment will be always full at the end of the night period, assuming that minimum flow in the summer will be at least 10 l/s (even if minimum flows are lower the reasoning will be the same). If the source flow is more than 10 l/s, the extra discharge will overflow via a weir to the second 5 l/s-capacity compartment. If the source flow is more than 15 l/s the extra discharge will overflow from the second compartment to the third 5 l/s-capacity compartment. If the source flow is larger than 20 l/s, this will finally overflow to the irrigation channel. There will be only one inflow structure located at the 10 l/s capacity reservoir. Overflow weirs will be installed between the first and the second compartments, between the second and the third compartments and between the third compartment and the irrigation channel (by-pass). All compartments will require outflow orifices which have to be dimensioned in a way such that linear outflow will take place during the day period. Following the arithmetic example in Appendix V, the 10 l/s-capacity compartment will need a diameter of 6.0 cm for the outflow orifice and the 5 l/s-capacity compartments a diameter of 4.3 cm.

In this way a reasonable linear decreasing outflow over the plots could be achieved for the whole range of source flows between 10 and 20 l/s.

A weak point in this whole reasoning is, of course, that source flows are variable and unpredictable (in reaction of precipitation in the river basin) although they tend to reduce in the course of the summer. That is to say that the resultant outflow of two turns from a reservoir in general will not be equal across all the plots in a *casal* as is supposed by the constant source flow during the two turns, as assumed in Figure 7.3. However it can be argued that later irrigation turns are increasing in value because of more water scarcity later in the growing season. That means that although the last user in an irrigation turn has less water, he will be the first to be compensated in the next irrigation turn in which irrigation water has a higher value. Moreover there are other compensation mechanisms that could mitigate this variability, e.g. the annual alternation of the sequence in the first turn of the year. Whatever it may be, this question can best be examined by a simulation of the combined yield and soil moisture availability effects of variable source flows and the linearly decreasing outflow of the night reservoir on different situated plots during the growing season. This simulation -with help of the CROPWAT program- is shown in Box 7.3.

Box 7.3 Combined effects of variable source flows and the linear decreasing outflow of a night reservoir

Here I will compare -by simulation with the help of the CROPWAT program- the effect on yields and the variation of the soil moisture during the growing season of the situation without reservoir and the situation with reservoir, respectively at the most upstream plot and the most downstream plot in a *casal*.

Assumptions for simulation

- Two maize fields of 0.18 ha: one upstream, one downstream in a *casal*
- Soil type: loam with potential root depth of 1 m.
- Climatic data: ETo and average rainfall of Vila Real (Appendix III, Table 2)
- Crop: grain maize; planting date: 1-5
- canal and application losses not considered
- water right for the plots: 1.5 hours/11 days; first irrigation: 1 July
- assumed flow pattern of the water source (see Table below)
- reservoir outflow pattern according to Figure 7.3

These assumptions result in the following combinations of irrigation dates, source flows and field application depths (see Table below)

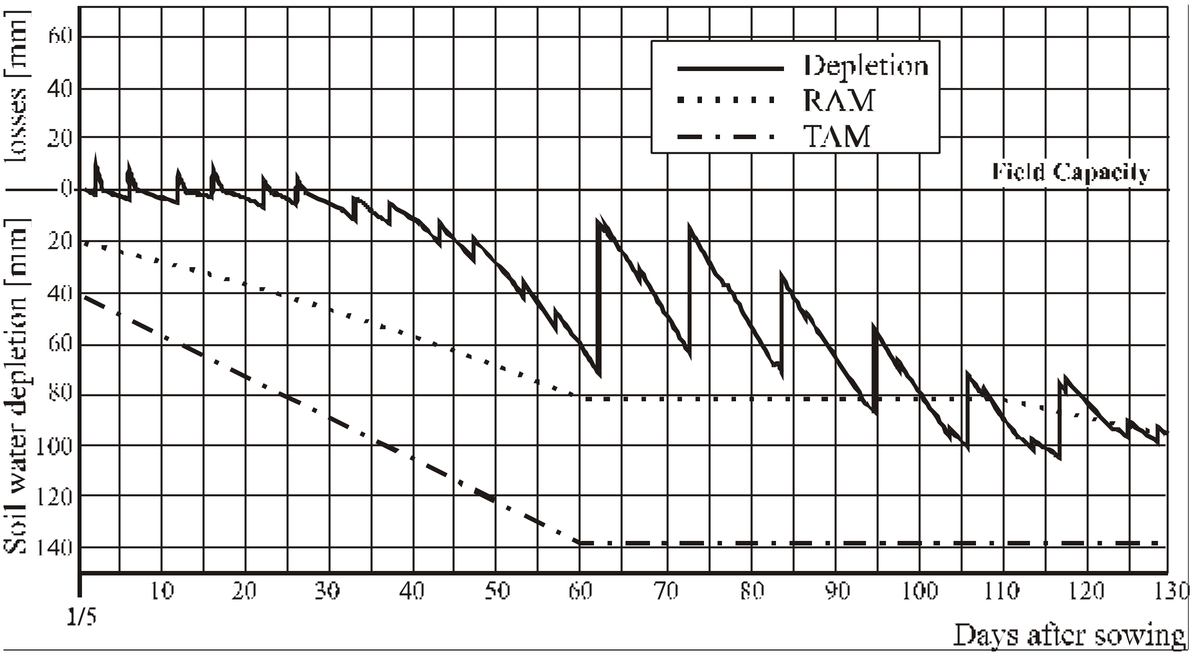
Irrigation turn		Source flow (l/s) (assumed)	Application depths (mm)		
Date	Sequence		Without reservoir	With reservoir, Upstream plot a	With reservoir, Downstream plot z
1-7	a →z	20	60	68	52
12-7	z →a	16	48	42	55
23-7	a →z	13	39	44	34
3-8	z →a	11	33	29	38
14-8	a →z	10	30	34	26
25-8	z →a	10	30	26	34
Seasonal application depth (mm)			240	243	239

Notes:
* The assumed hydrograph of the source flow reflects a realistic discharge pattern during Summer (the source flow is decreasing considerably during Summer).
* Calculation application depths:
- Without reservoir: Source flow [l/s]* 1.5 [h] *(3600/1800)
- With reservoir:
. First plot in sequence: Source flow [l/s]*1[h]*(3600/1800) + reservoir outflow volume during first hour in m3/1.8
. Last plot in sequence: Source flow [l/s]*1[h]*(3600/1800) + reservoir outflow volume during last hour in m3/1.8

Results of simulation

Without reservoir
- Yield reduction: 5 per cent
- Soil moisture variation during the growth season: see Graph below

Without reservoir: soil moisture variation diagram



Note:
For an explanation of concepts used in the Graph, see Box 5.3.

With Reservoir, Upstream plot a
- Yield reduction: 3 per cent
- Soil moisture variation diagram is very similar to the one without reservoir

With Reservoir, Downstream plot z
- Yield reduction: 6 per cent
- Soil moisture variation diagram is very similar to the one without reservoir

The simulation shows that the difference in yield reductions between the three distinct situations (without reservoir, an upstream plot with reservoir flow and a downstream plot with reservoir flow) are negligible. This is also reflected in nearly identical soil moisture depletion diagrams. The simulation also shows that the effect of a reservoir is mainly a difference in application depths between the plots in the successive irrigation turns but seasonal application depths are about the same. At least, this is valid under the condition that the reservoir and its operation are well designed, i.e. an outflow pattern in which differences between maximum and minimum outflow are limited, which in turn implies a relatively large surface area of the reservoir and a relatively large 'dead' storage and consequently a larger reservoir than strictly necessary on the basis of the needed capacity to store 'night' flow.

It can be concluded that the functioning of a night reservoir with a linear outflow may very well be compatible with the actual water allocation schedule under varying source flows[17]. In other words, the water distribution resulting from the operation of such a designed night reservoir is an alternative way of realising the existing water allocation schedule.

The final question is how such a reservoir could be located on the terrain. That requires precise topographical survey of the local situation. Probably the existing diversion dam in the river needs to be raised. The functioning of the night reservoir and the necessity of additional structures, e.g. a spillway to accomodate floods in winter must be analysed under different river flow conditions.

Effects of the night reservoir on water management

I have shown in the foregoing that it is possible to design a night reservoir with simple operational requirements that is compatible with the actual water allocation.

In this case, a night reservoir even has some 'unexpected' synergic effects. A first important effect is that the effective irrigation time (i.e. the time that farmers are effectively irrigating their fields) could be reduced by 33% (=1-(16/24)) applying the same quantity of water, consequently labour input and labour productivity of irrigation activities could be decreased respectively increased by about 33 per cent. Second, the functioning of the system could be simplified. Under the condition that all actual time shares will be shortened by one-third (e.g. an actual time share of 1.5 hours will now be 1 hour), the division into 3 subgroups within a *casal* will lose its meaning. The *água salteada* sequence (see Chapter 3.2) can be eliminated and the irrigation turns within a *casal* can be simplified to two sequences, that is upstream to downstream (a→z) and downstream to upstream (z→a) as discussed in the foregoing. Third, because of fewer water 'jumps' this solution reduces canal losses. Finally, an additional advantage is that the tail end will receive more water than in the actual situation (*ceteris paribus*) because in the downstream to upstream sequence, tail enders will be the first to receive water from the reservoir, which will be more than the channel flow in the actual situation (the relative large outgoing flow when the reservoir opens, 'pushes' the water, as it were, more rapidly to the tailend than in the actual situation with lower canal discharges).

Thus a correctly dimensioned night reservoir has the potential to resolve five interrelated problems at the same time: night irrigation will be eliminated, the labour input in irrigation activities will be reduced by about 30 per cent, the complexity of the water distribution can be simplified, water losses in the canals could diminish and the tail end will receive more water.

Elimination of the ’meia água’ period

Another complexity can also be eliminated, namely the *meia água* period. This period has its origin in the past when there was a rigid distinction between the summer and winter irrigation periods and respective summer and winter irrigation areas to which water was allocated. Before the 24th June all irrigation water was used for mills and *lameiro* irrigation. In this period water could not flow to the *veiga*. *Meia água* could be considered as a meaningful rule to respond to the pressing demand for water of most users at the start of the summer period when food crops in the *veiga* area (potatoes and maize planted in April/May) were in need of water. Because nowadays water is permitted to flow to the *veiga* area before the official start of the summer period, this pressing demand does not exist anymore (when farmers need water for their crops they have access to it through the *a vez* rule). Thus, *meia água* has become an anachronism, the rule has lost its meaning and consequently can be eliminated.

The construction of a night reservoir, the abolition of the *salteada* sequence and the elimination of the *meia água* period are simple interventions and measures to improve and to simplify the functioning of the system. They will respond to demands and constraints felt by local water users and adjust -at least in part- the system to changed conditions.

The night reservoir and the related changes in allocation and distribution rules are the most obvious with the *highest potential impact* but surely not the only possible interventions. Other additional or alternative interventions are possible that have the potential to improve gradually the functioning of the irrigation system. Some can be implemented in steps, according to one of the proposed intervention strategies in Chapter 7.2, others imply profound changes in the management of the system.

Additional water

Two of these interventions are aimed at increasing the availability of irrigation water:

- *the exploration of new sources*

Local farmers state that there are various sources in the mountains that have not been used until now. Intuitively I do not believe that this measure could be very effective in the sense that it will yield much more water. In general, most accessible water sources in Trás-os-Montes are already used and if sources exist that are not explored they are certainly small, for instance an additional source of 1 l/s will only contribute about 5 per cent to the actual discharge. Moreover the investment will probably be expensive.

- lining of additional irrigation channels
Within the implemented MRT intervention about 20 per cent of the length of the primary irrigation canals has been lined (the main canal between river intake and bifurcation point and the head ends of the two channels after the bifurcation point, see Figure 3.4). It has been measured that considerable losses (dependent of the source flow about 20-40 per cent of that flow) still occur in the parts that are not lined (Stam 1993; Carvalho 1994). Lining of these parts will surely bring more water to the tail end of the system. This measure (possibly combined with exploring more water sources) will also increase flexibility in operation of the system by decreasing transport times.

Reordering of irrigation turns

In *comparison to other Trás-os-Montes' systems*, the labour efficiency of field irrigation in the Vila Cova system is reasonable. That is directly related to the comparatively high channel discharges (10-20 l/s compared to systems with source flows of <1 l/s). A factor that increases the labour input in Vila Cova irrigation is the scattering of irrigation activities, the consequence of a historical process of increasing fragmentation resulting from inheritance practices etc. For instance, a water user has to irrigate plot (a) on day x and time k, then plot (b) on day y and time i etc. All those turns one has to walk to the plot, be there before one's neighbour finishes his irrigation time etc. However, it must be noted that the upside of these labour-demanding irrigation practices is that an efficient use (i.e. with minimal water losses) of available water resources is made, another crucial characteristic of this irrigation system. This was fully justified in a situation in which -for most farmers- available labour was relatively abundant in relation to available irrigated land and water resources. However, nowadays labour is becoming the scarcest resource for an increasing number of farm households. For them, optimising the resource labour is the driving force behind their (changing) way of farming. It implies that the labour-demanding irrigation practices need to be transformed into less labour-demanding and more labour-productive irrigation practices. The Vila Cova irrigation system and its functioning needs to be adjusted so that it can accommodate the new demands posed to irrigation.

But here the limits to change appear. The only way to further decrease labour input in irrigation and enhancing labour productivity is by a *reordering of irrigation times*. The idea is that the different irrigation times of a user will be concentrated in one or two periods. This implies that the actual irrigation sequence that is mainly governed by the location of adjacent plots will be substituted by a sequence of water users[18]. This would involve profound changes in the management of the system. The *casal* as a specific group of water users combined with specific plots during one day would lose its meaning, irrigation sequences would be organized on another principle. It could also mean that the length of the irrigation interval needs to be adjusted. At present this is 11 days, too long for shallow-rooting crops such as vegetables. In the actual situation it is exactly the scattering of the irrigation periods during the irrigation interval that enables irrigating these crops more often within the interval. There are also trade-offs. Given the scattering of the plots, the reordering of irrigation times implies 'jumps', longer travel times of water and consequently higher water losses. Thus a higher labour efficiency in irrigation activities is realised at the cost of decreasing water use efficiency (higher water losses). However, the lining of additional irrigation channels and higher average stream flows as a consequence of night reservoir operation could counterbalance this loss of water use efficiency.

Finally, a combination of a high labour efficiency and water use efficiency could only be obtained by a combination of reordering of irrigation turns and irrigated plots. This last intervention implies a type of land consolidation[19].

Conclusions from the Vila Cova case

What conclusions can be drawn from this case?

First, that there are strong *interrelationships* between the technical (infrastructural) and managerial (allocation and working rules) dimensions of an irrigation system. So, changes in the infrastructure may imply changes in water management and vice versa. It has been shown that in the Vila Cova' communal irrigation system this interaction has a potential for *synergic* effects.

Second, that a suitable improvement plan must be drawn up starting from the *local situation and its opportunities*. In this case the preconceived and uniform MRT intervention certainly has (partially) resolved the problem of water losses in the irrigation canals but other specific problems and the local opportunities to solve them have not been taken in account.

Third, that meaningful interventions will have to focus on the *changes in the context* in which farming and irrigation practices are embedded. FMIS and actual irrigation practices are the products of historical local society and traditional agriculture. However, the latter contextual elements have seen great change, the functioning of the FMIS is –as it were- lagging behind in the adjustment to new conditions.

Fourth, that the improvement of a system could be divided into different logical steps in which former steps could condition later steps.

Fifth, that a balance must be sought between *conflicting objectives* (for instance, between practices that lead to a lower labour input and practices that are directed at the most efficient use of scarcely available water).

In synthesis, I have shown that the redesign of this system should center on the interrelated changes in three basic elements: *irrigation infrastructure (a system night reservoir and its specific design and use), water allocation (decreasing time shares) and water distribution (rules and mechanisms to compensate for varying reservoir outflow). This combination of interrelated changes signifies a potential for improvement and adaptation of this system to a context of labour scarcity.*

Without a *thorough knowledge* of the functioning of the actual system and the local context it is difficult or perhaps impossible to propose meaningful improvements. Even then, it is impossible to foresee beforehand if and how such an improvement plan could be implemented. Some water users will agree to some proposed interventions, others maybe will not and vice versa. Vested interests of some water users could veto changes etc. Some changes are easier to implement than others. Some interventions need other resources than others. Some changes need external support (e.g. technical knowledge to design a night reservoir), others could be treated at the local level. In short, an adequate improvement plan and its implementation must be created at the level of the locality.

7.4 A repertoire for redesign in FMIS

After having discussed on a detailed level the possible redesign of the Vila Cova communal irrigation system, I will now attempt to derive some general insights concerning the redesign of FMIS. I will also formulate a repertoire of redesign that could also be applied elsewhere, covering the diversity of FMIS in Trás-os-Montes in particular and Portugal in general.

I will depart from three basic considerations. First, the existent water availability in FMIS is limited by hydrological and ecological conditions. However, in the endogenous farming pattern of the 'intensifiers' the dependency on scarce summer water for fodder production is (very) small in contrast to the exogenous farming patterns. Second, changes in water allocation and distribution are to be integral elements of intervention. Third, labour scarcity is to be taken in account as one of the fundamental features to be resolved (at least partially) through the proposed intervention. It is exactly the contribution to less demanding and labour intensive irrigation practices that a *considerable potential exists to redesign FMIS* as I have shown in the redesign proposal of the Vila Cova communal system.

From the aforegoing considerations a repertoire of potential technical and managerial measures and interventions to improve and to redesign FMIS can be derived. The alternative interventions will be combinations of improved or new irrigation facilities, adjustments of water allocation and distribution mechanisms. Although there are interactions, they can be divided schematically into the following three categories:

- to increase and redistribute water availability
- changes in water management
- interventions with a labour saving potential

Increase and redistribution of available water

** lining of water diversion structures, reservoirs and irrigation channels*
This is the standard technical measure of the MRT intervention. Lining in itself definitively does not create more water but it could make more water available to productive FMIS areas by limiting losses from these infrastructural elements. Other beneficial effects are the decrease of transport times in the irrigation channels (flexibilizing water distribution) and labour consuming conduction of water to the plots. So, lining could constitute an important potential for improvement but it has to be selectively applied, taking in account what is the nature of these losses, where and in which degree losses occur, e.g. an actual 'loss' which is now used in a certain place by certain water users may -after lining- be a gain in another place by other water users. Every scheme has its particularities in this respect. It reinforces the intervention strategy

to use farmers' local knowledge in determining the channel parts where most losses occur and where lining is the most effective.

** The construction of permanent diversion weirs*
When applicable (FMIS dependent on surface water resources) this is normally a standard measure of the MRT intervention, diminishing diversion losses[20]. It will also eliminate the labour needed for the reconstruction of temporary weirs.

** Exploring and developing additional water sources*
The suitability of this measure depends on the local situation. In general, I think, the potential of this measure is not high because most water sources are already exploited. The cost of constructing new water works and to explore less accessible water will be high. Yet, in some villages there will certainly be limited room for exploiting more water. However, in many cases this intervention will not create extra water but redistribute already existent water and has even the potential to undermine existing FMIS. In selecting investments for individual water resources development subsidies by State programmes no criteria exist that take into account the interference with already used water sources.

** Designing an effective legislation concerning water resources development*
The aim of this measure will be to regulate ongoing processes of undermining traditional water sources and redistribution of available water. Although this measure is mainly the competence of the national government, the practicality and success of this measure depend on many factors at the local level. Most important in this respect are the cohesion of local society and the strength or erosion of communal institutions.

Changes in water management

** Changes in water allocation principles*
Some water allocation principles, particularly the plot-based principle, restrict the use of water. It permits neither the irrigation of meadows nor transactions with water. This is in contradiction with the changing conditions of the last decades in which the importance of food production is diminishing and scarcity of labour leads to extensification of land use and an increasing importance of meadow production. Plot-based allocation is also in contradiction with the creation of farm or field reservoirs. The time share allocation offers farmers (e.g. pluriactive farmers) -possibly in combination with farm or field reservoirs- more flexibility in using the water in the way that is most convenient to them, i.e. in relation to the objectives, resources, perspectives and potential of their farming system.

Technically, the change from plot-based to time-share allocation is not so difficult in case of a permanent field flow (24 h/day). In principle, it involved converting the size of the irrigated plots in proportional time shares, if necessary corrected by a factor that accounts for the differential effects of water losses related to the distance between water source and plot. However, such a situation does not frequently occur. Mostly, plot-based allocation is associated to the operation of reservoirs. However, a change from plot-based to time-share allocation is very difficult in the case of existing reservoirs as will be shown later in this chapter. The existing reservoirs are not designed to obtain a certain outflow pattern which, combined with compensatory mechanisms, allows time-share allocation of the outflow (see the Vila Cova's improvement proposal). To design such a type of reservoirs, engineers' knowledge is needed.

** Decreasing the complexity of water distribution rules and practices*
The complexity and the often related high and rigid labour demand of water distribution in some systems is felt by an increasing number of users, principally the young and pluriactives, as a constraint in the use of these systems. In some systems, there is a strong need to simplify the operation of irrigation and make it less time-consuming.

** Reducing the length of the irrigation interval*.
In some systems, irrigation intervals are too long (e.g. 30 days) from a maximum yield perspective. In this cases a decrease of the length of the interval would seem a real improvement with productive effects. It is technically no problem to decrease the length of irrigation intervals, but that needs to be accompanied by a proportional reduction of water rights (e.g. expressed in irrigation time shares[21]) per turn and consequently in application depths. Allowable and suitable intervals depend on cultivated crops and soils. This question can be examined by the effects on yields and variations of the soil moisture through simulation with the CROPWAT program.

Table 7.2 shows how suitable irrigation intervals are strongly interrelated with soils (loam vs. sand), crops (root depth of maize vs. potato vs. vegetables) and plot location (head vs. tail, canal losses assumed).

Table 7.2 Relative Yield reductions as function of interval, soil, crop and canal losses

Climatic data: ETo and average rainfall of Montalegre (Appendix III)
Water right for plot of 0.12 ha: 3 hours/30 days; 2 hours/20 days; 1 hour/10 days
Hydrograph of water source: Figure 1 in Appendix III

Soil (Appendix III)	loam	loam	sand	loam
Crop (Appendix III)	maize	potato	maize	vegetables
sowing/planting date	15-5	26-4	15-5	15-5
Root depth	1m	0.6 m	1m	0.4 m
Plot at canal Head end (0 % losses)				
Interval:30 days	18	37	42	>50
20 days	13	29	36	>50
10 days	11	16	32	35
Plot at canal Tail end				
Unlined (50% canal losses assumed)				
Interval:20 days	41	41	>50	>50
Lined (20% canal losses assumed)				
Interval: 20 days	23	32	>50	>50

From Table 7.2 it may be concluded that given a certain water source and its flow pattern during the summer, a short interval in general is favourable although the effects on yield in certain situations (dependent on crop and soil type) are minimal and within the margin of error in the model calculations and assumptions (deviations between model and reality). The simulation shows for instance that the difference in productive effects on a maize field with a deep loam soil is not as large as one would expect at first sight. However a shorter interval will also increase the fragmentation of irrigation activities and delivery times. This implies an increase in workload. Therefore, knowledge of the local situation (dominant soils and importance of crops, available water, canal losses, labour input irrigation activities) is crucial to an assessment of what constitutes a suitable irrigation interval in that situation.

Interventions with a labour-saving potential

** The (re)construction of irrigation reservoirs*

Reservoirs have a very considerable potential for improving the functioning of the actual irrigation systems. In the following I will elaborate on that and discuss related questions.

Reservoirs could have different (combined) functions. The two most important functions are:

- *Flow regulation*. Such reservoirs aim to enable irrigating fields with a larger flow than the original source flow. This represents a labour-saving potential. These reservoirs already exist in many systems, principally in those with low source flows in which they are a pure necessity. They can be constructed at system and/or (distribution) group[22] and/or farm and/or plot level. At farm and plot level these reservoirs also have other advantages. First, they permit a more flexible and improved timing of field water application, not prescribed by the rigidities of the system such as e.g. a long irrigation interval. Second, reservoirs permit more flexibility in labour input. The individual user can store the water during the night or another period and apply the water at the most appropriate moment, a very relevant solution for pluriactive farmers. Reservoirs also facilitate the use of other field irrigation methods such as sprinkler irrigation. Conditions for implementing these reservoirs are generally favourable but complications may occur. Topographical conditions may dictate that water be stored under surface level which implies pumping. A reservoir also takes up space so that cultivable land will be lost. Furthermore it could be an expensive investment.

- *Night storage*. These reservoirs aim at eliminating the drudgerous practice of irrigating food crops at night in summer. At the same time they represent a labour-saving potential. In many systems night storage is combined with flow regulation.

The construction of a new reservoir must be accompanied with changes in water distribution (rules and practices) and changes in water allocation i.e. the bundle of water rights and/or the principle by which they are distributed. This has been shown in the improvement plan of the irrigation system of Vila Cova. But the relation between reservoir operation and water distribution is not deterministic, that is, the variable outflow from a reservoir can be allocated and distributed in various ways. For instance, water users in Vila Cova have different options for distributing the water of a reservoir: instead of distributing the flow in time shares at two levels (system and *casal* level) as actually occurs, they could also choose to change the allocation principle, e.g. plot-based implying a water distribution on the basis of a fixed sequence of determined plots which are ‘sufficiently’ irrigated (See Chapter 2.4). In that case reservoir design (dimensions of reservoir and outflow valve) need not be very precise and operation (e.g. opening times) can be more flexible. However this means a change from time-shares to plot-based water allocation, a very problematic question which needs to be agreed on by the water users. Such a change also implies the introduction of rigidities (fixed plots, no meadow irrigation, plot reservoirs are rendered useless) which are characteristic for the plot-based allocation. This is surely not in the interest of groups such as e.g. pluriactive farmers.

The outflow of a reservoir is distributed in different ways related to the allocation of the inflow for Trás-os-Montes' systems with actually existing reservoirs as shown in Table 7.3.

Table 7.3 Inflow allocation and Reservoir outflow distribution in Trás-os-Montes' FMIS

Inflow allocation	**reservoir volume**	**outflow distribution**
- long time share	time share*inflow	individual
- short time shares	time shares*inflow	flow division in small groups
- long equal time shares	time share*inflow	individual
- First come, first serve	*poçada* (a reservoir full)	individual
- Two level time-plot	time share*inflow	fixed plot sequence+ compens. mechanisms (plot-based)
- More level allocation	time share*inflow	plot-based and/or flow division+ compens. mechanisms

This table shows that in systems with existing reservoirs the outflow is never distributed according to time shares. This is not accidental: this arrangement would require carefully designed and dimensioned reservoirs based on hydraulic principles as shown in the case of Vila Cova. This is not within the realm of local knowledge but would require engineers' knowledge. In existing reservoirs the precise outflow pattern is not a critical parameter (see Figure 2.9). That is clear in the case water is stored sequentially by individual water users because the whole reservoir volume of one time share is for one water user. In the case that water is stored by more users at the same time (e.g. distribution groups) the effect of the variability of the outflow is smoothed out by a combination of specific allocation principles (plot-based and flow division) and compensatory mechanisms (see Chapter 2.4 and 3.1). In all these cases the design and operation of reservoirs are simple and transparent but they are not compatible with a time-share distribution of the outflow.

A reservoir with a linear outflow as a function of time, permitting a distribution of the outflow on basis of time shares, is a new technical option. It has the potential of broadening intervention perspectives in FMIS. It can be used as a *new intervention tool* in various situations, both in systems in which no collective reservoirs exist yet and in systems where users wish to modify the functioning of their system, e.g. a change from plot-based to time-share allocation.

In conclusion, the allocation of the inflow, the use (design and operation) of reservoirs and the distribution of the reservoir outflow are related to each other in specific ways in order to be mutually compatible.

* *Substituting small reservoirs by larger-capacity reservoirs*
In many systems with low or extremely low discharges (<2 l/s), water is stored in small system reservoirs. Each water user or group of water users (distribution group, see Chapter 2) stores the water corresponding to his or their time shares in the reservoir. Opening and closing of reservoirs must be executed at the right moments which is a laborious task in case of short time shares and/or far distances between farmsteads and reservoir.

Labour input could be considerably reduced and flexibility in labour input increased if existing reservoirs could be amplified or new reservoirs could be constructed that have a larger capacity e.g. to store the source flow of one week or one whole irrigation interval or part of it. That creates the opportunity to concentrate all irrigation activities of all water users in one limited time period e.g. one day in a week or in an irrigation interval and consequently to save considerable labour time in irrigation activities.

This may be illustrated with the following example. Suppose that with the actual reservoir operation and time share allocation (of the inflow) the water users need on average about 30 per cent of their time share to realize field irrigation (i.e. outflow time is 30 per cent of the inflow time). Also suppose an irrigation interval with a length of 10 days. That signifies that in this interval 0.30*10*24= 72 hours of labour input are required for irrigation activities. Let me compare this situation with a new larger capacity reservoir that is emptied every 10 days (the length of the irrigation interval). Assume that in the last 12 hours of the irrigation interval this reservoir will be emptied and all water users will irrigate in this 12-hour period. Then the labour time in field irrigation will be reduced by 72-12=60 hours or (60/72)*100= 83%. Total labour time will be even reduced more because opening and closing of the reservoir need to be done only once in the irrigation 10-day interval.

It can be concluded that the concentration of irrigation activities in a relatively limited period by means of larger capacity reservoirs has a considerable labour-saving potential. But there are various implications and questions that need to be addressed. Average channel and application flows increase about 6 (= 72/12) times, so canal capacities must be reviewed[23].

Water distribution rules and water use practices need to be adapted to this new situation if the original water rights or water shares are to be maintained. To guarantee a correct conversion of rights into distributed water, varying source flows could be compensated for through periodic changes (for instance, during the summer irrigation season, from year to year etc.) in irrigation turn sequences (see Chapter 2.4 and 3) and varying reservoir outflow could be compensated in ways as indicated in Table 7.3 or -as is described for the Vila Cova case- with a linearly decreasing outflow as a function of time. Principally the combination of relatively large capacities reservoirs with a linear outflow pattern has a great potential for broadening the scope of intervention. With this type of reservoirs intervention can be extended to labour saving in all FMIS with allocation principles that define rights to water quantitatively.

Apart from the labour saving potential these larger reservoirs have two additional advantages. First, the operation time of these reservoirs could be better adapted to the needs of pluriactive farmers, for instance on Saturdays when they have more time for farming activities. Another advantage is that the water flow is more concentrated reducing canal losses. That also gives the opportunity to irrigate tailend plots that in the actual situation cannot be irrigated.

This way of storing water in reservoirs for longer periods combined with compensatory mechanisms builds on and further develops actual irrigation practices and, I think, could represent a large and promising potential to improve these practices and to save on labour.

** Accounting in the technical design for the use of new field irrigation methods.*
To new water application methods like sprinkler and drip irrigation, frequently, miraculous water-saving and labour-saving properties are ascribed. However, this potential in Trás-os-Montes is limited because of the scatteredness and small size of plots. Much labour is required to move equipment (pumps, tubes, sprinklers) from one field to another field etc. Also sprinkler irrigation could be very labour intensive and drudgerous e.g. transport of tubes from muddy places and high crops (maize) to other parts of the field. On the other hand, trickle irrigation and micro-sprinklers are not compatible with the type of cultivated field crops in the research area[24].

Nevertheless, some farmers are using and experimenting with sprinkler irrigation, albeit mostly on a very small scale. Often it concerns individual independent sources and systems. Farmers normally have only some sprinklers which are moved periodically. The labour-saving potential consists in that the sprinklers -once put in place- can be left unattended for e.g. 4 to 12 hours. However, this method in many cases signifies considerable investments such as the construction of reservoirs and the acquisition of equipment such as motor pumps, sprinklers and tubes. To include (low pressure) sprinkler irrigation or drip irrigation (in case of e.g fruit trees) in the technical design, at least partially, might in some cases be an option in the improvement of traditional irrigation schemes e.g. in the case that the water source is on a much higher location than the irrigated fields so that pumping is not necessary. But to convert a whole system to pressurised irrigation is no *sinecure*. It means a radical change in the operation and maintenance of the system and users have to give up their traditional irrigation practices. On the other hand individual farmers who have built their own plot or farm reservoirs can integrate (partially) these new irrigation methods in their way of farming.

Conclusions

From what is discussed it is clear that the parameters, variables, factors and elements that determine the functioning of irrigation systems are *strongly interrelated*. The direct relation between required labour input in field irrigation and the field discharge has already been shown but many other relations exist between the different elements of an irrigation system. If one infrastructural or managerial element is changed than it has consequences for the other elements that constitute the irrigation system and it has repercussions on the functioning of the whole.

In my opinion there are - apart from the flow characteristics of the water source(s)- three *existing elements* that are crucial to the actual functioning of Trás-os-Montes' FMIS. First, *water allocation*, which determines who has rights to use the water and how these water rights or shares are distributed among the users. This element offers the necessary security for users to receive the share of the available water to which they are entitled. That does not mean that changes in water allocation (principles) are not possible but these changes must fit within the existing distribution of water shares amongst the right holders.

A second existing element is the *compensatory mechanisms*. In the translation of water allocation into water distribution in Trás-os-Montes systems, these mechanisms and rules are fundamental to equalising variations in streamflow and operating conditions so that water users could realise their water rights in a way that is on average equal for all water users. I think that this is a crucial, albeit underestimated[25], element in (re)designing irrigation systems. Once established, these compensatory mechanisms work, so to say, automatically, with hardly any monitoring or management costs involved.

A third existing element is the *reservoirs*. In comparison with situations without reservoir, they make irrigation more efficient, both in restricting water losses (higher flows result in relatively less canal losses) and labour input. Reservoirs thus have a water-saving and labour- saving potential.

The functioning of every FMIS could be characterised by specific combinations of these three existing elements. The *redesign of FMIS could be centered around these three basic elements*, which determine the functioning of the systems: *water allocation* (principles), *the use of reservoirs* and *water distribution rules* (compensatory mechanisms). New orderings between these interrelated elements signify a considerable potential for improvement and adaptation of these systems to a changing context. *Alternative interventions might focus on a new ordering between these already existing elements.*

I have shown that it is exactly the translation of rights into water use that contains a hidden potential of improvement interventions. Reservoirs combined with compensatory mechanisms represents a promising potential to explore for the improvement and adaptation of actual irrigation systems. Particularly, I have identified two possible new interventions that constitute an considerable labour saving potential (not only in a quantitative sense but also qualitatively, for instance the elimination of night irrigation) compared with already existing reservoirs: first, the design of reservoirs with a linear outflow as function of time which permit extending the use of reservoirs to all irrigation systems with time-share allocation and which also permit changes in water allocation principles (from plot-based to time shares); second, the creation of relatively large-capacity reservoirs, storing water for longer periods.

Box 7.4 provides a very rough estimate on different levels of the *labour saving potential* of the above-mentioned reservoir interventions. This yielded the following results:

- System level: on average 75 work days/summer season (year) per FMIS
- Regional level (Trás-os-Montes): 75,000 work days/summer season (year)
- National level (Continental Portugal): 1,350,000 work days or 5,600 labour years per year[26]

It can be concluded that the *potential impact* is considerable regarding the three here considered levels.

In this chapter I have made an analysis of problems of FMIS in Trás-os-Montes in their specific and changing context. Based on this analysis and their actual functioning I have explored the potential for the redesign of FMIS in Trás-os-Montes. In my opinion the underlying reasoning, searching for coherence between the physical and institutional dimensions related to changing contexts, could also be applied in one way or another to redesign or improve the functioning of many systems worldwide, not only of FMIS but also of the functioning of tertiairy units of large systems.

It will be clear that the repertoire of improvement measures is much more ample than the actual MRT intervention, aimed at the reduction of canal losses. Although interventions need to be adapted to the characteristics of each system, I have shown that this new type of interventions can be based on already existing elements in the systems and building on the actual logic of functioning of these systems, be developed further. This new type of interventions maintain the fundamental characteristics of FMIS, for instance the sharing of scarce water by means of water rights and low transaction costs, but at the same time allowing for more efficient and labour saving irrigation practices, particularly adapted to the actual context of labour scarcity.

Finally, what I have discussed in this chapter supports the central thesis in this book stating that there is a considerable potential entailed in the skill-oriented technologies embodied in FMIS which can be developed further. However, potential is one thing, whether this potential could be realised is another. This will strongly depend on the local situation, local perspectives and local actors but also on the action of external actors. Each system has its own characteristics and specific context. In some cases the unmistakable tendency towards the creation of individual irrigation facilities will be dominant, hinder the realisation of interventions in FMIS and even undermine FMIS. For certain categories of farmers, particularly those who have access to capital and subsidies, investing in the development of individual sources is an easier way than contributing to changes in FMIS. In other cases the status quo and vested interests will be so strong that stagnation and involutionary tendencies will continue. On the other hand, external actors (State agencies, engineers etc.) could support the realisation of this potential by collaboration, facilitation and supplying resources that are locally unavailable. But this support will have to depart from the situation as it is and not from an assumed or ‘virtual’ reality.

Box 7.4 Estimate of the impact on labour-saving potential of reservoir interventions

System level

I will consider two common situations, one without reservoir and one with existing small reservoirs. First, in an irrigation system without reservoir, for instance the irrigation system of Vila Cova, irrigation in the summer period takes place continuously (24 hours/day). In this situation the total number of hours that water users are in fact irrigating (field irrigation) in the summer period can be estimated as: 24*90 = 2160 hours. With a night reservoir, seasonal labour input is 16* 90 = 1440 hours (8 hours night storage) or 12*90 = 1080 hours (12 hours night storage). On this basis, the labour-saving potential of the night reservoir can be estimated as 720 hours/season (90 working days of 8 hours) to 1080 hours/season (135 working days).

Second, an irrigation system with existing small-capacity reservoir. Suppose that in the actual situation 30 per cent of the length of the summer period (90 days) is used for field irrigation. This corresponds to a labour input of 0.3*24*90 = 648 hours/season or 72 hours/10 days. Suppose that with a larger-capacity reservoir, irrigation will be concentrated in 12 hours per 10-day irrigation interval, labour input becomes about 108 hours/season. On this basis, the labour saving potential of a larger capacity reservoir amounts to about 540 hours/season or 67 days.

Regional level (Trás-os-Montes)

Assuming that in Trás-os-Montes about two thirds of the systems already have reservoirs and one third do not have reservoirs yet, the labour saving potential of new and large-capacity reservoirs can be estimated about 75 days/season for an average FMIS in Trás-os-Montes. Taking an estimated 1000 FMIS in Trás-os-Montes (DGEA 1980) then the labour-saving potential on a regional scale can be estimated at -by rough extrapolation- about 75,000 days per season.

National level (continental Portugal)

In continental Portugal about 550,000 ha is irrigated by FMIS (DGRAH 1987). On basis of data in Fernandes (1988), Freund (1992), Vida Rural (1992), IFADAP (1994), Larcher Graça (1998), the average area of an FMIS in Portugal can be estimated at 30 ha. Then the quantity of systems can be very roughly estimated at 18,000 in continental Portugal. Assuming that there is a labour-saving potential of 75 days/season/system, total labour saving potential per season on the national level can be estimated as 18,000*75 = 1,350,000 work days or 5,600 labour years.

Notes

1 These (monetary) labour incomes are more or less comparable to the Portuguese minimum wage income in 1989 of about 40 *contos* per month. In reality farm labour incomes are higher because use values (e.g. food, house, fuelwood) and any off-farm work are not taken in account which in particular could form a considerable income part of small explorations (Baptista *et al.* 1990). On the other hand, for most farm households, it is not the national minimum income that is taken as the point of reference but the income possibilities out of migration.

2 This clearly depends on local conditions. Currently, availability of land resources is not a serious limiting condition in many villages (Ribeiro 1997: 406). On the other hand, if this expansion has to be financed by the credit system, this could lead to lower incomes (pers. comm. Dirk Strijker).

3 The most important shortcomings are the neglect of the mutual dependency of different farming patterns and the importance of off-farm income generating activities within the different farming patterns. However the data available does not allow to take them in account (Oostindie *et al.* 1995).

4 Farmers say: '*A terra precisa de comer'* (the soil needs to eat). The importance of organic manure (*estrume*) is also reflected in popular expressions like *uma pessoa bem estrumada*, literally 'a well-manured person' but meaning a person with abundant financial resources (Cristóvão *et al.* 1994).

5 A clear example is the category of the SCOM farmers. The SCOMs stimulated enormously the development of dairying in small farms (1-5 cows) which realise the lion's share of milk production. However, these small farmers were excluded the access to PDRITM farm assistance and the later '797' grants for farm development.

6 However paradoxical it may seem, it is the local possibilities to meet work and income sources outside agriculture, which has the potential to strengthen farming and local village life.

7 However, in the early 1990s, coinciding with the implementation of the quota system in the dairy sector, agricultural policy started to shift in the direction of more attention to the exploration of local resources and region specific high-quality products. This could be seen as an attempt to strengthen endogenous development possibilities. The question whether and in which degree this shift has consolidated in later years is outside the scope of this thesis.

8 I refer to Cristóvão *et al.* (1994) and Oostindie *et al.* (1995) for a review of this issue and alternative intervention strategies. It might be worthwhile to experiment with village-based investment funds (e.g. to improve FMIS, baldios etc) This would build more closely on the Barroso tradition of village-based social organisations (formal and informal) and in some ways complements the policy of transferring traditional State services to emergent farmers' organizations. Certainly a village-based allocation of investment funds will create its own specific problems. However, in Barroso the village is undoubtedly the most appropriate social organisation for dealing with the allocation of investment funds. In some ways village-based investment funds already exists in Barroso. This is a consequence of the afforestation of the commons (see Box 2.3 and Brouwer 1995). However, little is known about intra-village processes in respect to the management of these funds (Oostindie *et al.* 1995).

9 An important question in this respect is the definition of the quality concept i.e. related to the breed itself or related to the breed and the way it is produced. In the former case it would probably only mean a change in the orientation of the production, with the same built-in selectivity which so far characterised agricultural policy. In the latter case, as the use of *lameiros* and *baldios* in the feeding of the breed will be integrated in the concept of quality meat, also smaller farmers could benefit (Cristóvão *et al.* 1994)

10 One of the most labour-intensive activities in farming is the production and processing of hay. Labour shortage has led to contradictory tendencies regarding the use of lameiros. On the one hand many cultivated (irrigated) plots are converted into *lameiros*. On the other hand some existent *lameiros* are abandoned or gradually extensified (for instance using the *lameiros* only for pasturing), in particular those that require too much labour to harvest them. Farmers abandon their own low-quality *lameiros* and at the same time hire productive *lameiros* from other farmers (Morgado 1993). This shows that the existing supply of mechanization is not adapted to field conditions of steep slopes, precarious drainage, difficult access and small plots.

As an example I will describe what a colleague and myself observed at the end of July 1993 in Pitões de Junio (Barroso), a lively village in which 'traditional' farming, oriented to meat production, is dominant. Many farmers in Pitões are well equipped with tractors, bailers and other equipment for hay preparation and harvesting but the productivity of this type of equipment is terribly low compared to its productivity in conditions for which the equipment was originally designed. During one hour we observed the process of hay bailing (*enfardar*) on a plot of about 0.1 ha. The plot had a considerable slope and was quite small so that the tractor and the bailer were not able to move further than about 30 metres. Turning around was impossible so the combination of tractor and bailer only could move backwards and forwards with difficulty. Seven people were involved in the work, one on the tractor, two others gathering and casting the hay in the bailer, two people pulled hay and bales away from the combination and guided its backward voyage and two others raked the hay which was lost in the process. The neighbouring plot was so steep that a tractor-and-bailer combination could not access it. So the workers raked all the hay from the highest point in the field to the lowest point close to the road where it was gathered and loaded onto a cart and transported into the village. There the cart was unloaded and the hay was bailed by stand-by equipment. These situations are not exceptional in large parts of Trás-os-Montes.

11 In 1993 some farmers in Barroso bought a big-sized manure spreader. Although manure spreaders can help a lot in diminishing labour input and workload, the above-mentioned manure spreader seems an impracticable tool for the majority of the farmers who work small plots.

12 Bleumink *et al.* (1992) mention a cost ceiling of 400 ct/ha or 3,000 US$/ha in 1990.

13 People in some villages mentioned the formerly existence of an *Instituto de Reforma Agrária* created after the 'Carnation' Revolution of 1974 which supported local water supply projects with e.g. construction materials complementing the labour of the village habitants. Another example is the village Gallegos de Serra in which the local habitants in 1974 substituted 500 meters of earth canal by a canal constituted by half-circular concrete elements (*meia manilhas*). These elements were supplied and transported to the village under an order of the then *governador civil* of the Vila Real district.

14 The lined parts of the canals have been designed (GAT 1985) as if the source flow would be divided proportionally between the two primary canals after the bifurcation point (see Figure 3.4) This shows a lack of understanding of the functioning of the system. In most Trás-os-Montes systems source flows are seldom divided (an exception is the Romainho system but only at lower levels, see Chapter 3.2), so mostly only one water user at the time is irrigating with the whole source flow which facilitates monitoring and control.

15 There is no compelling reason to take 8 hours as the length of the night period. The period between 8 p.m and 4 a.m. coincides more or less with the period of darkness in the summer but otherwise is an arbitrary value. The choice of another length of the night period will make no difference in the reasoning.

16 This range of source flows was measured in the summer of the 'dry' year 1992.

17 Although, there are also other ways of reservoir outflow regulation. In some irrigation systems in Ecuador, night reservoirs are equipped with a float-controlled valve aimed at a constant reservoir outflow. It is claimed that this device achieves a maximum outflow variation of 10 per cent (CESA 1997, 2000). However, when applying of such a device in the Vila Cova system, an operational complexity would be that the outlet valve needs to be adjusted to varying source flows, which could be a source of error and conflict. Moreover, this solution is relatively expensive (about 1500 US$). The functioning of a reservoir with a linear outflow – if it is well designed- is wholly automatic, apart from the closing and opening of valves (on-off regulation) at the beginning and end of the night period.

18 A sequence of water users is characteristic of systems with an 'equal time shares' water allocation schedule. Under this water allocation principle, each water user have only one irrigation period in an irrigation interval (see Chapter 2.4) for all plots he wants to irrigate. The same occurs in some irrigation systems with reservoirs: e.g. a farmer has a unique period of 12 hours storage, once every fortnight. With this water he has to irrigate all his plots located in the area served by the irrigation system.

19 The Portuguese State considers land consolidation fundamental and even a panacea for the restructuration of the agricultural sector. However, the problems related to land consolidation are many and highly complex. Till now, the results of land consolidation programs in Portugal have been

extremely poor. During much time the lack of results served even as a pretext to postpone other State support to the zones in which small holders dominate (Baptista 1999:273).

20 However such an intervention could prejudice more downstream systems in case they depend on the same river or surface water resource.

21 For instance a 10-hour water right in a 30-day interval is equivalent to a 5-hour water right in a 15-day interval.

22 In the village Galegos de Serra with a relatively long primary irrigation canal with derivations to distribution groups (two-level time-plot allocation) along the canal, some of this groups have created reservoirs, also to store water during the night.

23 Taking the aforegoing example and assuming a maximum source flow of 1 l/s, the storage capacity of the reservoir has to be equal to 9.5*24*3600*0.001 = 821 m3. Average canal flow can be calculated as 821/(12*3.6)+1 = 20 l/s. The canal discharge capacity, dependent on reservoir and orifice dimensions, needs to be higher.

24 However, trickle irrigation is increasing in some irrigated areas of Trás-os-Montes like the *Terra Quente* where fruit and olive trees are dominant.

25 I wonder why the irrigation literature rarely refers to such mechanisms (and when they do, they are treated as insignificant details) which are fundamental for the translation from abstract rights into water use in the field, a basic element in the functioning of any irrigation system.

26 Given that in 1991 about 400,000 people (10 per cent of the total working population) worked in the farming sector (Larcher Graça 1998), this represents about 1 per cent of the total working time in agriculture.

Appendix I Calculation Model Used for the Comparison of Water Use in the Exogenous and Endogenous Farming Patterns. Variables, Assumptions and Algorithms

The relevant raw accountancy data of the farms are represented in the VARIABLES rubric. In the sample of 39 farmers, 6 had outspoken characteristics of the 'modernisers' farming pattern and 12 of the 'intensifiers' farming pattern. The accountancy data of these 2 categories of farmers have been used to analyse the differences in irrigation water use. Based on the VARIABLES, a straightforward calculation model has been constructed. Relevant parameters and indicators related to irrigation water use have been determined for each farm belonging to the two categories. The calculated parameters in Table 5.2 are the averages of the two distinguished farmer categories.

The critical assumptions and relations of the calculation model are (original accountancy data in *italics*) :

- It is assumed that hay meadows are not irrigated in the Summer and that the whole acreage of Summer crops is irrigated. Then: Acreage (SAU) irrigated summer crops = *SAU (potato + green forage maize+fodder beets+corn maize + silage maize + temporary meadows*).
- It is assumed that all irrigated meadows are primarily for hay production (*lameiros de feno*). Then: SAU irrigated meadows= *SAU irrigated* - SAU irrigated Summer crops and: SAU unirrigated meadows ('*lameiros de pasto'*) = *SAU lameiros*- SAU irrigated meadows ('*lameiros de feno*')
- It is assumed that irrigated Summer crops serve to satisfy the subsistence needs of the farming household (vegetables, corn maize, potatoes), to sell surpluses (potatoes) and to produce cattle feed (green maize, fodder beets, silage maize and temporary meadows but also a not specified part of the potato and corn maize production).Then: SAU irrigated summer fodder = SAU irrigated summer crops- SAU irrigated area for subsistence needs- SAU potatoes sold under the condition that SAU irrigated summer fodder > *SAU (green maize + fodder beets + silage maize + temporary meadows)*
- It is assumed that the net irrigation water requirements of the summer crops are roughly 250 mm or 2500 m3/ha with exception of potatoes and green maize which irrigation requirements are estimated in 150 mm or 1500 m3/ha because of a shorter growing season (green maize) or a smaller part of its growing season is in the water scarcity period (potatoes).

Additional assumptions are mentioned in the model (ALGORITHMS AND ASSUMED RELATIONS).

* VARIABLES:		UNIT
- *v1*	*: SAU total*	*(ha)*
- *v2*	*: SAU irrigated*	*(ha)*
- *v3b*	*: SAU potato*	*(ha)*
- *v3c*	*: SAU green forage maize*	*(ha)*
- *v3d*	*: SAU fodder beets*	*(ha)*
- *v3e*	*: SAU corn maize*	*(ha)*
- *v3f*	*: SAU green rye forage*	*(ha)*
- *v4*	*: SAU silage maize*	*(ha)*
- *v5*	*: SAU temporary meadows*	*(ha)*
- *v3*	*: SAU lameiros*	*(ha)*
- *UHT*	*: Labour units*	*(UHT)*
- *v25*	*: Sold potatoes*	*(ct=1000 esc.)*
- *v9*	*: Standard unities meat cattle*	*(CU)*
- *v9a*	*: Standard unities dairy cattle*	*(1.5*CU)*
- *v17*	*: Purchased concentrate*	*(ct=1000 esc.)*
- *v18*	*: Purchased forage*	*(ct=1000 esc.)*
- *v29*	*: Output meat production*	*(ct=1000 esc.)*
- *v30*	*: Output milk production*	*(ct=1000 esc.)*

* ALGORITMS AND ASSUMED RELATIONS

(1)	Cattle density: (*v9*+1.5**v9a*)/*v1*	(CU/ha)
	It is assumed that 1 milch cow=1.5*CU and 1 meat cow=1 CU (Cattle Unit)	
(2)	% SAU irrigated: 100**v2/v1*	(%)
(3)	SAU irrigated Summer crops: *v3b+v3c+v3d+v3e+v4+v5*	(ha)
(4)	% SAU irrigated Summer crops: 100*(3)/*v1*	(%)
(5)	SAU irrigated *lameiros*: *v2*-(3)	(ha)
(6)	% SAU irrigated *lameiros*: 100*(5)/*v1*	(%)
(7)	proportion *lameiro*/summer irrigation: (5)/(3)	-
(8)	SAU non-irrigated *lameiros*: *v3*-(5)	(ha)
(9)	% SAU non-irrigated *lameiros* : 100*(*v3*-(5))/*v1*	(%)
(10)	acreage irrigated *lameiros* per Cattle unit: (5)/(*v9*+1.5**v9a*)	(ha/CU)
(11)	acreage non-irrigated *lameiros* per Cattle unit: (8)/(*v9*+1.5**v9a*)	(ha/CU)
(12)	SAU irrigated area for subsistence needs: 0.15**UHT*	(ha)
	It is assumed that 1 UHT need about 0.15 ha irrigated summer area for subsistence needs.	
(13)	SAU potatoes sold: *v25*/240	(ha)
	It is assumed that average yield of potato crop is 10,000 kg/ha and average price for potatoes sold is 24 esc./kg	
(14)	SAU irrigated summer forage: (3) -0.15**UHT*-*v25*/240	(ha)
	under the condition that (14) >*v3c+v3d+v4+v5*	
(15)	acreage irrigated summer forage per cattle unit: (14)/(*v9+1.5*v9a*)	(ha)
(16)	% SAU irrigated summer forage: 100*(14)/*v1*	(%)
(17)	SAU irrigated 'modern' summer forage crops: *v4+v5*	(ha)
(18)	% irrigated 'modern' summer forage of total area of summer irrigation:	

100*(*v4+v5*)/(3) (%)

(19) acreage modern irrigated summer forage per cattle unit:
(*v4+v5)/(v9+1.5*v9a*) (ha/CU)

(20) area green rye forage per cattle unit: *v3f/(v9+1.5*v9a*) (ha/CU)

(21) purchased concentrate per cattle unit: *v17/(v9+1.5*v9a*) (ct/CU)

(22) purchased forage per cattle unit: *v18/(v9+1.5*v9a*) (ct/CU)

(23) irrigation requirements of summer fodder crops: 1500*v3b+1500*v3c+
2500*v3d+2500*v3e+2500*v4+2500*v5-2500*0.15*UHT-1500*v25/240 (m^3)
under the condition that (23) > 1500*v3c+2500*(v3d+v4+v5)
Estimated average net crop irrigation requirements in the summer period in
Barroso are: potato and green forage maize: 1500m^3/ha; other crops: 2500m^3/ha

(24) 'scarce' summer water requirements per cattle unit: (23)/(v9+1.5*v9a) (m^3/CU)

(25) gross income per unit of scarce water used in the irrigation of summer
fodder crops: 1000*(v30+v29)/(23) (esc./m^3)
only the output of dairy production is considered

(26) net income per unity of scarce water used in the irrigation of summer fodder crops
I am indebted to Henk Oostindie for the calculation of the values of the
average net incomes for the two categories of farmers.

Appendix II Comparative Model Study of Irrigation in Two Contrasting Farming Patterns

To check the broader applicability of the results regarding irrigation water use in contrasting farming patterns (see Table 5.2) based on an empirical analysis of a limited quantity of farm accountancy data, a comparative model study has been carried out. Based on the characteristics of the two contrasting farming patterns, ideal-typical farm models are constructed which I have assumed representative for the two patterns. Then fodder requirements and irrigation requirements for each farm model are calculated. Finally, these farm models are compared regarding irrigation water use and labour requirements in irrigation activities.
For a summary of the typical assumed indicators and characteristics of these farm models, see the Table below.

Assumptions

- 1 Meat cow= 1 CU (Cattle Unit); Milch cow = 1.5 CU
- The presence of small ruminants (goats and sheep) is not considered because they rely minimally on irrigation water and it is a relatively independent branch on the farms.
- Farm acreage: average owned and hired land.
- The quantity of cattle and land are related to the values of cattle densities in Christovao et al. (1994). Exogenous pattern: 0.8 milch cow/ha (1.2 CU/ha); Endogenous pattern: 1.4 CU/ha. Pigs, calves and small ruminants are not considered in cattle density.
- Average lactation period (period between successive calf births): one year. It is assumed that the whole of lactation and dry periods of the cows are uniformly distributed over the year.
- Assumed productivity of reproducing cows: 0.8 calf/cow/year (data from Lima Santos, 1992:185)
- Exogenous farm model: Except the calves that will replace old cattle they are sold as soon as possible (up to 1 month) after they have born; no sheep and other ruminants.
- Endogenous farm model: assumed cattle breed is *Barrosã*. Calves are sold at an age of 5-7 months.
- Assumptions for the calculation of gross values: farm-gate prices: milk: 50 esc/litre; calves up to one month: 30 ct/calf; calves of 5-7 months: 100 ct/calf (125 kg*800 esc/kg): potato: 25 esc/kg. It is assumed that 2/3 of the potato harvest will be sold at the market.
- It is assumed that the production of the garden, the grain maize (0.25 ha) and 0.25 ha potato is used for the subsistence needs of the farm household.
- Types and quantities of cattle fodder depends on the farming system (see farm models)
- Assumed cropping pattern depends on the farming system (see farm models). A first distinction is made between a small vegetable area (for household consumption needs), *lameiros* (permanent meadows: irrigated hay/ pasture lands and unirrigated pasture lands) and arable land (with a rotation of annual crops).
- Proportion *lameiros*/ arable land is according to farm accountancy data.
- Proportion irrigated/ not irrigated land is according to farm accountancy data.

- The intensive use of *common lands* as the dominant fodder resource (by pasturing) for about 6-7 months (April/May till September/October) is assumed in the endogenous farming system of intensive meat producers.
- Assumed crop rotations of arable plots depends on the farming system (see farm models).
- Green rye can only be sown if the foregoing crop is harvested before the end of August, that is only after rye, potatoes and forage maize. Green rye cannot be conserved so it must be consumed at the time it is available (2 periods: pasturing in November and green cuttings in March/April). These two conditions set respectively under and boven limits to the area that is cultivated with green rye.

Assumed typical parameters and indicators of farm models

Parameters/Indicators	*Exogenous farm model (intensive milk farmers)*	*Endogenous farm model (intensive meat producers)*
Cattle (number and type)	16 milch cows (24 CU)	20 meat cows(20 CU)
Farm acreage (ha)	20.2	15.3 ha
Labour (l.u)	2	3
CU/l.u	12	6.7
Ha/l.u	10.1	5.2
* Crop type areas (ha, % SAU)		
- garden	0.2 ha (1 %)	0.3 ha (2 %)
- *lameiros*	9 ha (45 %)	9 ha (59 %)
- arable land	11 ha (54 %)	6 ha (39 %)
* Irrigated areas (ha, % SAU)		
- garden	0.2 ha (1 %)	0.3 ha (2 %)
- arable land	8 ha (40 %)	2.0 ha (13 %)
- total summer irrigation	8.2 ha (41 %)	2.3 ha (15 %)
- irrigated *lameiros*	6 ha (29 %)	6 ha (39 %)
- Total irrigated area	14.5 ha (70%)	8.3 ha (54 %)
* Cropping pattern (ha)		
- garden (irrigated)	0.2	0.3
- potato (irrigated)	0.75	0.75
- temp. meadows (irrigated)	4	-
- silage maize (irrigated)	3	-
- rye (not irrigated)	2	2
- green rye (not irrigated)	2	3
- *lameiros* (irrigated)	6	6
- *lameiros* (not irrigated)	3	3
- forage maize (irrigated)	-	0.5
- grain maize (irrigated)	0.25	0.25
* Use of commons for grazing	no	maximal
* Annual gross output	96,000 litres of milk	
(sold at the market)	13 calves (up to 1 month)	16 calves (5-7 months)
	5,000 kg of potatoes	5,000 kg of potatoes
* Annual gross value	5,315 ct	1,725 ct

Note: In the construction of these farm models and assumed indicators, I have tried to incorporate realistic farm characteristics as much as possible by using data from empirical material (Cristóvão *et al*. 1994; farm accountancy data), other sources (Lima Santos, 1992) and own observations.

- Modes of crop use as fodder:
  green rye (*ferrã*): pasturing in November, green cuttings in March/April.
  maize: green forage (stalks and leafs), milled grain, silage maize. Varieties (traditional, hibrid) and mode of use depend on the farming system.
  lameiros for pasture (not irrigated)
  lameiros for hay: pasturing Sept./Oct.; winter (3-4 months): no grass growth; growth period of hay: April until July. Only one hay cutting per year. July/Aug.: minimal growth.
  temporary meadow (sown meadow): 4-5 years, part of arable land , irrigated.

- Assumed 'good' yields
  potato (irrigated): 10,000 kg/ha
  lameiro (irrigated): 5600 kg dry matter (kgdm)/ha
  hay: 3,000 kgdm/ha
  pasturing: 2,600 kgdm/ha
  lameiro (not irrigated): 2,600 kgdm/ha
  pasturing: 2,600 kgdm/ha
  temporary meadow (irrigated): 6,600 kgdm/ha
  green cutting and grazing: 6,600 kgdm/ha
  grain maize (irrigated): 3000 kg/ha
  maize silage (irrigated): 6,000 kgdm/ha
  green rye: 1000 kgdm/ha
- For the calculation of required irrigation water are assumed the ecological conditions of mountain areas (see Appendix III).

Analysis

Intensive Milk Producers

Fodder and metabolic energy production

Ha	*Forage*	*April-Sept. (6 mth)*	*Oct-March (6 mth)*
6	irr. *lameiros*, grazing	6*2,000*2.3=27,600 Mcal	6*600*2=7,200 Mcal
6	irr. *lameiros*, hay		6*3,000*2.15=38,700 Mcal
3	dry *lameiros*, grazing	3*2000*2.1=12,600 Mcal	3*600*2=3,600 Mcal
4	irr. temp.meadow, grazing/green cuttings	4*6,000*2.7=64,800 Mcal	4*600*2.2=5,280 Mcal
3	irr. maize, silage		3*6,000*2.5=45,000 Mcal
2	green rye		2*1000*2.5=5,000 Mcal
	Subtotal	105,000 Mcal	105,000 Mcal
	Total Year: 210,000 Mcal		

Note:
- Fodder Production in ME (Metabolic Energy in Mcal)= Area (ha)* Dry matter production per ha (kgdm/ha)* Energetic value per kg dry matter (Mcal/kgdm)

Metabolic energy - requirements

Lactating cattle: daily required ME (Mcal)= Maintenance + ME required for milk production
$= 0.125*W^{3/4} + 1.25*DMP$ (W=cow weight; DMP = daily milk production)
Cow, 20 kg milk/day, weight 550 kg: $0.125*550^{3/4} + 1.25*20=39.2$ Mcal

Dry cows, say, 20 Mcal/day
16 cows, lactating 305 days/year: 16*(305*39.2 + 60*20)= 210,500 Mcal
Young stock, say, 10% of dairy stock
Total ME-req.: 1.1*210,500=232,000 Mcal
Required: April-Sept: 116,000 Oct-March: 116,000
Produced: April-Sept: 105,000 Oct-March: 105,000

Concentrate requirements, total: 22,000 Mcal (some 7 tonnes dry matter, or 400 kg/cow/year).

In the table below farm production according to the cropping pattern is translated into scarce irrigation water requirements.

Fodder production and water use

Crop/forage	*Area Ha*	*ME produced 10^3 Mcal*	*%*	*Net "scarce" summer water requirements m3*	*%*
- garden (irr.)	.2	n.a.	n.a	340	2
- potatoes (irr.)	.75	n.a	n.a	1400	9
- grain maize (irr.)	.25	n.a	n.a	420	3
- rye	2	n.a.	n.a	-	-
- green rye	2	5.0	2	-	-
- *lameiros* (not irr)	3	16.2	8	-	-
- *lameiros* (irr)	6	73.5	35	-	-
- temp. meadow (irr)	4	70.1	33	8320	51
- silage maize (irr)	3	45.0	22	5760	35
Total	21.2*	209.8	100	16240	100

Notes:
* 1 ha more than the farm acreage because of double cropping on 1 ha (green rye - potatoes/grain maize)
- Assumed Conditions in the calculation of net scarce summer irrigation water requirements: climatic data of Montalegre (Appendix III, Table 1) median rainfall (Appendix III, Table 3); loamy soil (Appendix III, Table 10); no water deficits; 'good' yields. Scarce irrigation water requirements correspond to Table 12 (Appendix III) based on crop water requirements calculated with the CROPWAT programme.

Forage production requires: 8320+5760=14080 m^3 of irrigation water. This is equivalent to 14080/24=587 m^3/cattle unit.

Gross value per m^3 of water: 5315/15020= 0.35 ct/m^3.

Quantity of milk per m3 of water: 6000/(1.5*587)= 6.8 liter/m3

Intensive meat producers

Fodder and metabolic energy production

Ha	*Forage*	*April-Sept.*	*Oct-March*
6	irr. *Lameiros*, pasturing	6*2,000*2.3=27,600 Mcal	6*600*2=7,200 Mcal
6	irr. *Lameiros*, hay		6*3,000*2.15=38,700 Mcal
3	dry *lameiros*, pasturing	3*2000*2.1=12,600 Mcal	3*600*2=3,600 Mcal
0.5	forage maize,	0.5*2,000*2.5=2,500 Mcal	
3	green rye		3*1,000*2.5=7,500 Mcal
?	Commons	+	+
	Subtotal	42,700 + Mcal	57,000 + Mcal
	Total Year:	99,700 + Mcal	

Metabolic energy requirements
Maintenance requirements of suckling cows (walking allowance included):
$1.2*0.125*W^{3/4}$=11.6 Mcal ME/day with an assumed weight of a *Barrosã* cow equivalent to 330 kg (Lima Santos 1992:249)
Maintenance requirements of calves: $1.2 * 0.125 * W^{3/4}$ = 3.3 Mcal ME/day with an assumed medium weight of calf equivalent to 60 kg. Average growing requirements of calves: 0.5 [kg/day]* 13 [Mcal ME/kg] = 6.5 Mcal ME/day
with an average live weight gain of 0.5 kg/day

Total ME required: 20*365*11.6 + 16*200*9.8= 116,000 Mcal/year

Required: April-Sept: 58,000 Oct-March: 58,000
Produced: April-Sept: 42,700 + Oct-March: 57,000 +

Pasturing in the commons fill in the gap between produced fodder and required fodder. Concentrate is hardly required, perhaps only to balance protein/energy requirements (protein meals/cakes).

In the Table below the farm production according to the cropping pattern is translated in scarce irrigation water requirements.

Fodder production and water use

Crop/forage	Area Ha	ME produced 10^3 Mcal	%	Net "scarce" summer water requirements M3	%
- garden (irrigated)	.3	n.a.	n.a	510	17
- potato (irr.)	0.75	n.a	n.a	1400	46
- grain maize (irr.)	0.25	n.a.	n.a	420	14
- rye	2	n.a	n.a	-	-
- green rye	3	7.5	6	-	-
- *lameiros* (not irr)	3	16.2	14	-	-
- *lameiros* (irr)	6	73.5	63	-	-
- green fodder maize	0.5	2.5	2	690	23
- commons	?	16.3	15	-	
Total	16.3	116	100	3020	100

Note:

- Assumed Conditions in the calculation of net scarce summer irrigation water requirements: climatic data of Montalegre (Appendix III, Table 1) median rainfall (Table 3); loamy soil; no water deficits; 'good' yields. Scarce irrigation water requirements correspond to Table 12 (Appendix III) based on crop water requirements calculated with the CROPWAT programme.

Fodder production (green fodder maize) requires: 690 m^3 of irrigation water. This is equivalent to 690/20=35 m^3/cattle unit.

Gross value per m^3 scarce water: 1725/1620= 1.06 ct/m^3.

Produced meat per m^3 scarce water: (16*125)/690= 2.9 kg/m^3

In the next table a comparison is made between the two farm models
Comparison of two farm models

Indicators	*Intensive milk producers*	*Intensive meat prod.*
1) proportion of scarce water req. for irr. food/ irr. fodder (m^3/m^3)	0.15	3.4
2) scarce summer water req. per CU (m^3/CU)	587	35
3) dependency fodder req. on summer irrigation (Mcal/Mcal)	0.50	0.02
4) dependency fodder req. on irrigated *lameiros* (Mcal/Mcal)	0.32	0.63
5) dependency req. fodder on rainfed land+commons (Mcal/McaL)	0.07	0.35
6) dependency fodder req. on concentrate [Mcal/Mcal]	0.11	nil
7) gross value per m^3 scarce water [esc/m^3]	350	1060
8) quantity of product (milk/meat) per m^3 scarce water	6.8 lts/m^3	2.9 kg/m^3
9) required continuous flow [l/s] at plot level(*)	3.45	0.64
10) irrigated summer forage acreage per cattle unit (ha/CU)	0.29	0.03

Note:
(*): Required continuous flow at plot level is calculated as:
(seasonal net scarce water req.*1000)/(0.9*60*24*3600) [l/s]
In this calculation is assumed a scarce-water period of 60 days and a water application efficiency of 90 per cent on plot level.

The contrasting farming patterns in terms of exogenous and endogenous development embody highly relevant differences with respect to irrigation water use and mobilisation. These differences are confirmed by the results of this farm model simulation study. It leads to the same conclusions as those obtained by the study of the farm accountancy data although the absolute values of the different parameters and indicators are different in the two studies. Analysing the table, main findings are:
- Parameter (1) shows how in the exogenous farming pattern 'scarce' summer irrigation water is mainly required for fodder production and in the endogenous farming pattern for food production. In the last pattern the irrigated summer forage (green maize) is clearly supplementar. It can even be substituted for more pasturing in the *baldios*.
- The requirements of scarce irrigation water per cattle unit are much higher under the exogenous than the endogenous pattern (parameter (2)).
- Parameters (3), (4), (5) and (6) show the dependency of fodder requirements on the diverse fodder supply components. Under the exogenous farming pattern fodder supply is mainly dependent

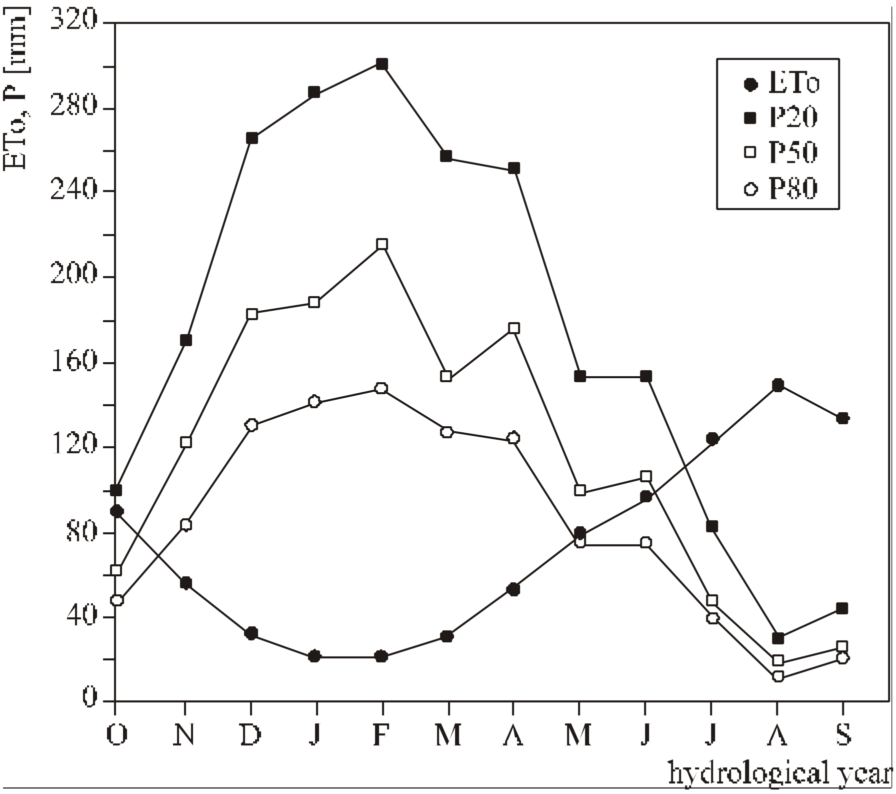
on summer irrigation while in the endogenous pattern a clear dependency exists on the *lameiros* and *baldios*. The exogenous pattern also depends on purchased concentrate.

- The input/output relations in terms of economic returns per unit of scarce irrigation water are much more efficient within the endogenous pattern (parameter (7).
- Parameter (9) shows a huge difference in irrigation water requirements between the exogenous and endogenous farm models. The irrigation requirements of five farms of the endogenous type are approximately equal to those of one farm of the exogenous type. Taking into account that the real availability of irrigation water in most villages is very limited in the summer period, it can be concluded that there is hardly room to accommodate the irrigation requirements of the exogenous farming pattern.

Variability of irrigation requirements

The scarce irrigation water requirements presented above have been calculated, assuming median rainfall and loamy soils. However to test the validity of the findings and conclusions presented above based on these scarce irrigation water requirements, it will be relevant to see the changes in these requirements in function of different rainfall regimes and soils. In the Graph below, the reference evapotranspiration ETo, which is a proxy of crop water requirements, is compared with the rainfall in a ‘normal’ year (P50), a ‘dry’ year (P80) and a ‘wet’ year (P20).

Agrohydrological Balance: Reference Evapotranspiration vs. Rainfall regimes



The Graph clearly shows that variability in rainfall between the years is mainly due to the rainfall variability in the winter months. In the summer months the variability in rainfall between the years is relatively small compared with crop water requirements (ETo) in these months. This small variability in rainfall in the summer months is clearly reflected in the small variability of irrigation water requirements between a 'dry' year and a 'wet' year. The Table below shows the difference in scarce irrigation water requirements of different crops between three rainfall regimes and the difference in soil moisture storage in the root zone between two soil types. The Table shows that the difference in scarce irrigation water requirements between a 'normal' and a 'dry' year (4) is relatively small (5-10%). It is less than the difference in soil moisture storage in the root zone between a loamy soil and a sandy soil (5). This implies that to explain the variation in irrigation water requirements, the difference between irrigated soils is a more important factor than the difference in meteorological conditions: loamy soil is much less sensitive to differences in rainfall conditions than the sandy soil. The greater soil moisture storage of loamy soil compensates better for dry conditions than that of sandy soil. Moreover, the retention characteristics of loamy soil allows for better field application efficiencies and less labour requirements in irrigation activities (larger water application depths, less irrigation turns). Therefore a loamy soil is an irrigable soil of higher quality than a sandy soil. This is of great importance because in Barroso there is a lack of high-quality irrigable soils which are needed for the expansion of irrigated lands for increased fodder production in the exogenous farming pattern. The great majority of lands in Barroso have poor soils. Deficiencies are small root zones, acidity, lack of phosphorus, aluminium toxicity. Good arable soils are scarce and man-made in Barroso. Their fertility must be maintained: the use of manure is very important. Traditionally, these man-made lands are preferred for summer irrigation of food crops. Although traditional irrigated summer areas are now increasingly used for fodder production, it is doubtful whether the required expansion of irrigated land for fodder production in the exogenous farming pattern can be fully realised within the traditional irrigation perimeters. Therefore, it can be expected that the development of 'modern' farms implies a need for additional irrigated land in summer. Given the shortage of good-quality lands and assuming that these lands are already traditionally irrigated this implies that the required expansion of irrigated land in the exogenous farm model need to take place increasingly on more marginal lands with poorer, sandy soils which traditionally hardly have any irrigation facilities, such as land which is traditionally used for rainfed rye production.

Irrigation Water Requirements in dependence of rainfall regimes, soil types and crops

** all values in mm*	*vegetables*	*potato*	*maize grain*	*green maize*	*Silage maize*	*meadows*
* Scarce irrigation water requirements:						
(1) in a 'normal' year (P50)/ loamy soil (a)	170	186	167	137	192	208
(2) in a 'normal' year/ sandy soil (a)	185	207	231	192	247	254
* Difference in scarce irrigation water requirements:						
(3) between a 'normal' year and a 'wet' year (P20)	-22	-29	-45	-27	-55	-54
(4) between a 'dry' year (P80) and a 'normal' year	+7	+7	+18	+8	+23	+24
* Difference in soil moisture storage in the root zone:						
(5) between a loamy soil and a sandy soil	15	21	64	55	55	46

Note:
(a): The way the irrigation water requirements are calculated is shown in Table 12, Appendix III

Estimation of required farm labour input in irrigation activities

On the basis of the farm model simulation study I will make an estimation of the required farm labour input in irrigation activities supposed that the required irrigation water quantities can be supplied in reality. To this end I assume a water source that is able to supply a continuous average flow at plot level of 10 litres/second, a hydrologic potential which can be considered representative for many irrigation systems in Barroso.
First, I calculate the required labour input in field irrigation (the activity of 'irrigating'). For field crops irrigated by existing surface methods, the required labour in field irrigation is calculated thus: (seasonal net scarce water req.*1000)/(0.9*10*3600) [hours] (Eq.1)
with seasonal net scarce water req. in [m^3] and an irrigation application efficiency of 90 per cent. For temporary meadows (contour ditch irrigation method, see Chapter 2) much less labour in field irrigation is needed under the condition that the plots are well prepared for irrigation. I estimate the required labour input in meadow irrigation as 10 per cent of hours calculated with (Eq.1)
To estimate the required labour time in additional irrigation activities it is assumed that:
- the average size of an irrigated field crop plot is 0.2 ha
- the average size of an irrigated temporary meadow plot is 0.5 ha
- in the summer months of July and August there are 6 irrigation turns per plot (length of irrigation interval: 10 days)
- required labour time in additional irrigation activities per plot per turn is 45 minutes

Then it is possible to construct the following table with estimated required labour times in irrigation activities.

Estimated required labour time in irrigation activities during the summer months July and August

Parameter/activities	*Labour time Exogenous farm model*	*Labour time Endogenous farm model*
Required labour time in field irrigation:		
(a) field crops	244	93
(b) temporary meadows	26	-
subtotal: a+b	270	93
calculation of required labour time in additional irrigation activities:		
(c) no. of irrigated field crop plots	21	9
(d) no. of irrigated temporary meadow plots	8	-
(e) no. of irrigation turns	6	6
(f) additional labour time per plot per turn (*)	0.75 hours	0.75
subtotal: (c+d)*e*f	130	41
TOTAL required labour time in irrigation activities	400	134

Notes:
- labour time in [hours]

(*) Included are the walk to the plot (vice-versa) and preparatory work (conducting the water from the channel to the field inlet, control and closing of other field inlets, routine maintenance of supply and field channels).

The above Table shows that about 400 labour hours in irrigation activities in the two summer months of July and August or 200 hours/month will be needed in the assumed ideal-typical farm representative for the exogenous farm model. This is three times more than the 67 labour hours per month needed in the assumed ideal-typical farm representative of the endogenous farm model.

Appendix III Data and Assumptions Used in CROPWAT Simulations

* *Climatic data*
Table 1: Montalegre
Table 2: Vila Real
Table 3: rainfall patterns Montalegre

* *Crop data*
Table 4: vegetables
Table 5: potato
Table 6: maize (grain)
Table 7: forage maize
Table 8: silage maize
Table 9: temporary meadow

* *Soil data*
Table 10: loamy soil
Table 11: sandy soil

* *Water supply pattern*
Figure 1: assumed hydrograph of water source

* *Irrigation water requirements*
Table 12: Scarce irrigation water requirements under conditions of median rainfall in Montalegre.

** Climatic data*

Table 1 Montalegre

Meteo station: Montalegre (1931-1961) Altitude: 1005 m *Coordinates: 41.00 N.L. 7.47 W.L.*								
Month	T_{ave} °C	RH_{ave} %	$Wind_{ave}$ km/day	Sun_{ave} hr/day	Rad_{ave} MJ/m2/day	ETo mm	P_{ave} Mm	Frost days
October	10.3	76	259	5.7	11.2	56	131	7.3
November	6.8	82	346	4.5	7.6	33	191	13.2
December	4.2	85	389	4.0	6.1	22	207	13.5
January	3.4	86	423	3.8	6.5	22	224	12.9
February	4.0	81	380	4.9	9.5	31	218	11.3
March	6.4	77	406	5.4	13.1	53	190	11.9
April	8.3	70	380	7.5	18.5	78	107	10.3
May	10.6	71	328	8.0	21.0	96	95	4.2
June	14.8	67	259	10.3	24.9	123	63	0.8
July	17.3	61	251	11.7	26.4	149	19	0.4
August	17.4	62	251	10.1	22.6	133	23	0.8
September	14.8	68	242	7.8	16.8	90	63	2.2
Year	9.9	74	326	7.0	15.4	886	1531	88.8

Source: INMG (1991)

Notes:
T_{ave} : average air temperature
RH_{ave} : average air humidity
$Wind_{ave}$: average windspeed
Sun_{ave} : average daily insolation
Rad_{ave} : solar radiation
ETo : reference evapotranspiration by Penman-Monteith calculated by CROPWAT (FAO 1992)

Table 2 Vila Real

Meteo station: Vila Real (1951-1980) Altitude: 481 m *Coordinates: 41.19 N.L. 7.44 W.L.*								
Month	T_{ave} °C	Rh_{ave} %	$Wind_{ave}$ km/day	Sun_{ave} Hr	Rad_{ave} MJ/m2/day	ETo mm	P_{ave} Mm	Frost days
October	14.4	74	156	54	11.1	53	100	0.5
November	9.4	80	166	46	7.4	27	136	6.0
December	6.6	85	175	33	5.3	19	156	9.2
January	6.4	84	170	34	6.0	22	164	8.9
February	7.5	78	202	42	9.1	34	166	5.7
March	9.6	73	206	44	12.8	59	134	1.5
April	11.8	68	211	52	17.7	84	77	0.6
May	14.9	67	194	57	21.3	112	69	-
June	18.5	64	185	64	23.9	135	47	-
July	21.4	57	185	78	26.0	164	14	-
August	21.1	58	182	76	22.7	143	17	-
September	18.8	66	154	61	16.2	90	49	-
Year	13.4	71	182	53	15.0	942	1128	32.4

Source: INMG (1991)

Table 3 Rainfall Patterns Montalegre

Climate station: Montalegre	*all values are in mm/month*					
Month	ETo	P50	P80	P20	P 77-78	P 70-71
October	56	122	84	171	166	12
November	33	183	131	267	95	325
December	22	188	142	288	373	65
January	22	218	148	301	175	405
February	31	154	126	256	371	42
March	53	176	124	252	150	136
April	78	97	75	152	139	153
May	96	106	76	154	90	149
June	123	48	40	82	31	132
July	149	18	13	27	0	153
August	133	26	22	44	1	86
September	90	64	49	100	32	4
YEAR Total	886	1400	1030	2094	1623	1662

Notes:
Rainfall values are calculated according to FAO method (FAO, 1992) from data of rainfall station Sezelhe (8 km from Montalegre) in the period 1943-1985.
P50: rainfall with 50% probability of exceedance, representing a 'normal' year.
P80: rainfall with 80% probability of exceedance, representing a 'dry' year
P20: rainfall with 20% probability of exceedance, representing a 'wet' year
P 77-78 represents an agrohydrological year with an extremely dry summer in which nearly all crop water requirements must be supplied by irrigation.
P 70-71 represents an agrohydrological year with an extremely wet summer in which nearly all crop water requirements could be met by rainfall and moisture stored in the soil.
Comparing evapotranspiration (ETo) with these rainfall values, it can be concluded that in nearly all years irrigation in the summer months is necessary.

** Crop Data*

Estimated values in the Tables adapted from FAO (1979)

Table 4 Food crops in the garden area (mix of cabbage, onion, beans, tomato etc)

Crop data:	*Vegetables*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	20	30	30	20	100
Crop coefficient [coeff.]	0.40	->	1.10	0.90	
Rooting depth [meter]	0.25	->	0.60	0.60	
Depletion level [fract.]	0.30	->	0.40	0.40	
Yield-response F. [coeff.]	0.60	0.60	1.00	1.00	1.00

Notes:
- Crop water requirement = crop coefficient * ETo

- Allowable depletion level represents the critical soil moisture level where first drought stress occurs affecting evapotranspiration and crop production. Values are expressed as a fraction of total available soil moisture (FAO, 1992).
- Yield response factor to estimate yield reduction due to drought stress.

Table 5 Potato for consumption (human and animal use)

Crop data:	*Potato*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	20	40	40	20	100
Crop coefficient [coeff.]	0.40	->	1.10	0.70	
Rooting depth [meter]	0.25	->	0.60	0.60	
Depletion level [fract.]	0.30	->	0.30	0.60	
Yield-response f. [coeff.]	0.45	0.80	0.80	0.30	1.10

Table 6 Maize (grain): human and animal consumption (concentrate and stalks)

Crop data:	*Maize (grain)*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	20	40	50	20	130
Crop coefficient [coeff.]	0.30	->	1.05	0.55	
Rooting depth [meter]	0.30	->	1.00	1.00	
Depletion level [fract.]	0.50	->	0.60	0.70	
Yield-response f. [coeff.]	0.40	0.40	1.20	0.40	1.20

Note: regional varieties

Table 7 Forage Maize: green harvested (leaf and stalks)

Crop data:	*Forage maize*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	20	40	20	20	100
Crop coefficient [coeff.]	0.35	->	1.05	1.00	
Rooting depth [meter]	0.30	->	1.00	1.00	
Depletion level [fract.]	0.60	->	0.60	0.60	
Yield-response f. [coeff.]	0.40	0.40	1.00	1.00	1.00

Note: regional varieties. Forage maize is harvested green, bit by bit, before great water stress develops (escaping from dryness)

Table 8 Silage Maize

Crop data:	*Silage maize*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	20	40	50	20	130
Crop coefficient [coeff.]	0.35	->	1.10	0.90	
Rooting depth [meter]	0.30	->	1.00	1.00	
Depletion level [fract.]	0.50	->	0.60	0.60	
Yield-response f. [coeff.]	0.40	0.40	1.40	1.40	1.25

Note: hybrid varieties

Table 9 Temporary meadow

Crop data:	*Pasture*				
Growth Stage	*Init*	*Devel*	*Mid*	*Late*	*Total*
Length stage {days]	90	90	90	90	360
Crop coefficient [coeff.]	1.00	->	1.00	1.00	
Rooting depth [meter]	1.00	->	1.00	1.00	
Depletion level [fract.]	0.75	->	0.60	0.60	
Yield-response f. [coeff.]	1.00	1.00	1.00	1.00	1.00

- *Soil Data*

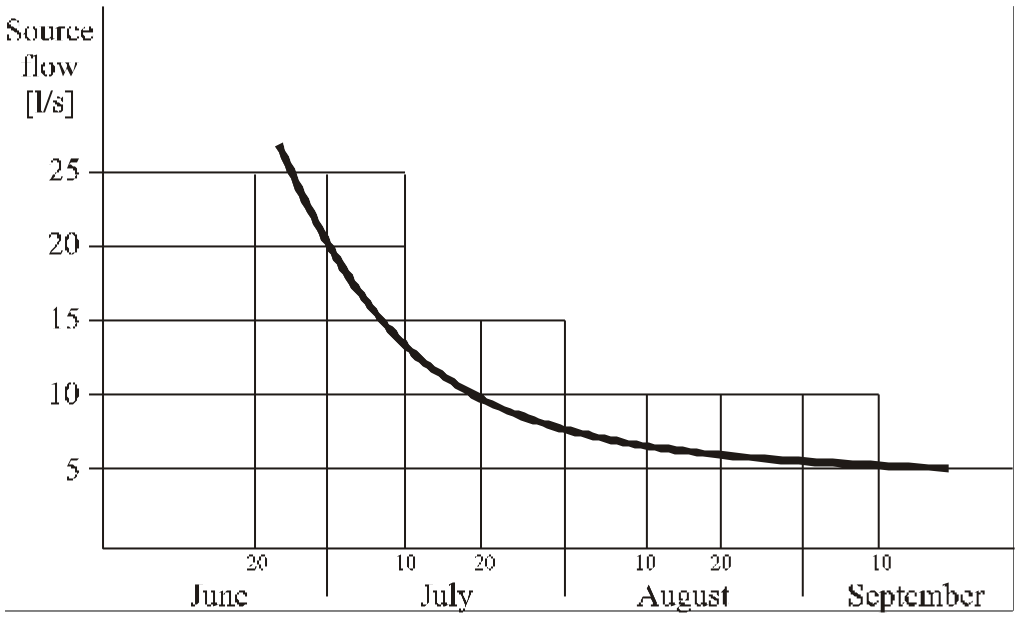
It is supposed that in Barroso there are two main types of soils irrigated in the summer. Permanent meadows or *lameiros* are not considered in summer irrigation because they are irrigated during winter and spring and hardly in the summer.

Table 10 *Loamy soil*
Texture: medium
Total available soil moisture(defined in FAO, 1992): 140 mm/m
Note: it is assumed that this soil type is representative for the traditionally irrigated summer areas close to the villages, traditionally used for food production. They are largely man-made, soil fertility and landscape being the result of intensive manuring and terracing.

Table 11 *Sandy soil*
Texture: coarse
Total available soil moisture: 80 mm/m
Note: it is assumed that this soil type is representative for the additional irrigated land required in the exogenous farming pattern for expanded fodder production. Frequently rooting depth is limited because of restricting soil layers.

- *Water supply*

Figure 1 Assumed hydrograph of water source



Note:
* The assumed hydrograph of the source flow reflects a hypothetical but realistid discharge pattern during the summer (the source flow is decreasing considerably during the summer).

- *Irrigation water requirements*

Table 12 Scarce Irrigation water requirements under conditions of Median Rainfall in Montalegre

** all values in mm* *Month decade of days*	*Vegetables*	*Potato*	*Maize grain*	*Green maize*	*Silage maize*	*Meadows*
June 1 (a)	5	8				17
2 (b)	25	26	9	10	3	26
June 3	35	35	21	22	15	31
July 1	42	42	36	36	29	38
2	49	49	46	46	44	44
3	43	45	43	43	45	41
August 1	35	38	40	39	42	38
2		27	37	36	39	35
3			28		30	26
September 1			15		21	18
2					10	9
Total irrig. Requirements (c)	**234**	**270**	**274**	**231**	**279**	**321**
Maximum Soil moisture storage in the root zone:						
Loamy soil(Sa=140 mm/m) (d)	**34**	**50**	**98**	**84**	**84**	**70**
Sandy soil(Sa= 80 mm/m; soil depth: 0.6 m) (e)	**19**	**29**	**34**	**29**	**29**	**24**
Scarce irrigation water requirements						
* loamy soil: total (c-a-b-d)	**170**	**186**	**167**	**137**	**192**	**208**
July 1	35	35	21	22	15	31
2	42	42	36	36	29	38
3	49	49	46	46	44	44
August 1	43	45	43	34	45	41
2		15	22		42	38
3					16	18
* sandy soil: total (c-a-b-e)	**185**	**207**	**231**	**192**	**247**	**254**
June 3	35	35	21	22	15	31
July 1	42	42	36	36	29	38
2	49	49	46	46	44	44
3	43	45	43	43	45	41
August 1	16	36	40	39	42	38
2			37	7	39	35
3			9		30	26

Notes:
- It is assumed that irrigation water is not scarce until the 3rd decade of June. At the end of the 2nd decade of June it is assumed that the potential root zone is at field capacity.
- Maximum soil moisture storage in the root zone: maximum rooting depth [m]* total available soil moisture content [mm/m] * allowable moisture depletion level (see crop and soil data).
- Scarce irrigation water requirements: irrigation water requirements from 3rd decade of June onwards less the maximum soil moisture storage in the root zone.

- Sowing/planting dates: vegetables: 1-5; potato: 20-4; maize grain: 10-5; green forage maize: 10-5; silage maize: 20-5; temporary meadow: 1-10

Appendix IV Outflow Pattern from a Reservoir with Inflow

Outflow conditions and outflow equation

Because of the topographic conditions (considerable slope allowing sufficient available head loss) semi-module flow conditions (free outflow, i.e. the outflow is only dependent on the water level in the reservoir and not dependent on the downstream water level in the canal) are assumed. Then, the outflow of a circular sharp-edged orifice could be expressed in the following formula:

$Q=C*A*(2gh)^{0.5}$ Equation (1) (ILRI *et al.*, 1978: 295) in which:

Q: outflow of reservoir [m3/s]
C: combined discharge coefficient [-]
A: wetted section of outflow orifice [m2].
For a circular orifice: $A= (pd^2)/4$ in which d: diameter of the orifice
g: standard acceleration of gravity (value: 9.81 m/s^2)
h: head above the center of the outflow orifice [m]

To prevent the entrainment of air, the water level in the reservoir should be at a height above the top of the orifice which is at least equal to the diameter of the orifice (ILRI *et al.*, 1978: 296). Thus the discharge equation (1) is valid for $h > 1.5d$.

Note: For $- ½d< h < ½d$ the orifice works as a circular sharp-crested weir with the following discharge formula :

$Q= C_e*f_i*d^{2.5}$ Equation (2) (ILRI *et al.*, 1978: 175) in which:

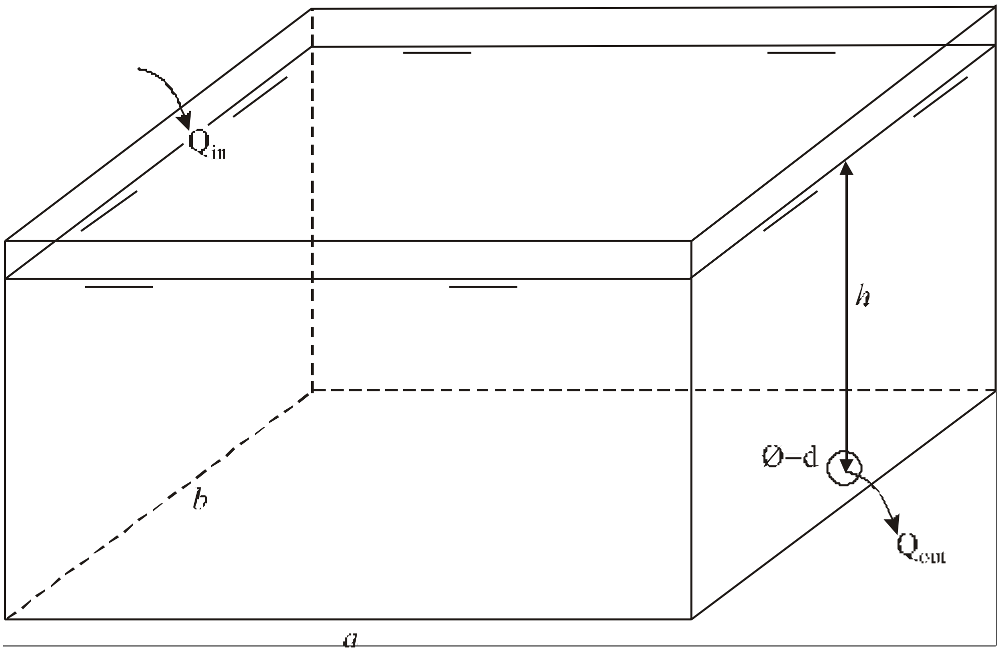
C_e: discharge coefficient
f_i : function of the filling ratio h/d
d: diameter of the orifice

For $1.5d<h< 0.5d$: flow through sharp-edged orifice but with entrainment of air so that equation (1) is not valid.

Analysis

$Q_{out} = Q_{in} - dV/dt$ with V=abh (see Figure below) and $Q_{out} = CA(2gh)^{0.5}$ (ILRI et al, 1978: 295)

Figure Reservoir with permanent inflow



$Q_{out} = CA(2gh)^{0.5} = Q_{in} - ab*dh/dt$ → $ab*dh/dt = Q_{in} - CA(2gh)^{0.5}$

from differential Equation: $(ab*dh) / \{Q_{in} - CA(2gh)^{0.5}\} = dt$
→ $t = \int [ab/\{Q_{in} - CA(2gh)^{0.5}\}]*dh$

→ $t = -2ab/2gC^2A^2 \ [\{Q_{in} \ln (CA(2gh)^{0.5} - Q_{in})\} + CA(2gh)^{0.5}] + K$ equation (3)

or: $t = -2ab/2gC^2A^2\{Q_{in} \ln (Q_{out}-Q_{in}) + Q_{out}\} + K$

from Equation (3) it follows that *the relation between h and t is not linear*.

Boundary conditions:
t= 0 (start of outflow) $h= h_{max}$ $Q_{max} = CA\ (2gh_{max})^{0.5}$

→ $K = 2ab/2gC^2A^2\{Q_{in} \ln (Q_{max} - Q_{in}) + Q_{max}\}$

→ $t = -2ab/2gC^2A^2\ \{Q_{in} \ln (Q_{out}-Q_{in}) + Q_{out} - Q_{in} \ln (Q_{max} - Q_{in}) - Q_{max}\}$ or:

$t = -2ab/2gC^2A^2[Q_{in} \ln\{CA(2gh)^{0.5} - Q_{in}\} + CA(2gh)^{0.5} - Q_{in} \ln \{CA\ (2gh_{max})^{0.5} - Q_{in}\} - CA(2gh_{max})^{0.5}]$

$t=t_f$ Q_{out} → Q_{in} suppose: $Q_{out\ min} = (1+x)Q_{in} = CA(2gh_{min})^{0.5}$ in which x → 0

Then: $t_f = -2ab/2gC^2A^2\{Q_{in} \ln xQ_{in} + (1+x)Q_{in} - Q_{in} \ln (Q_{max} - Q_{in}) - Q_{max}\}$ or:

$t_f = -2ab/2gC^2A^2[Q_{in} \ln xQ_{in} + CA(2gh_{min})^{0.5} - Q_{in} \ln\{CA(2gh_{max})^{0.5} - Q_{in}\} - CA(2gh_{max})^{0.5}]$ Eq. (4)

in which $ab = (24 - t_f)Q_{in}/(h_{max} - h_{min})$
Eq. (5) in which t_f in [hrs] and Qin = source flow [m^3/h]

Equation (4) and (5) give the interrelations between the various design parameters h_{max} , h_{min} , x, ab and CA with given Q_{in} and t_f .

Let me illustrate the dimensioning of the reservoir and outflow orifice with an arithmetic example:

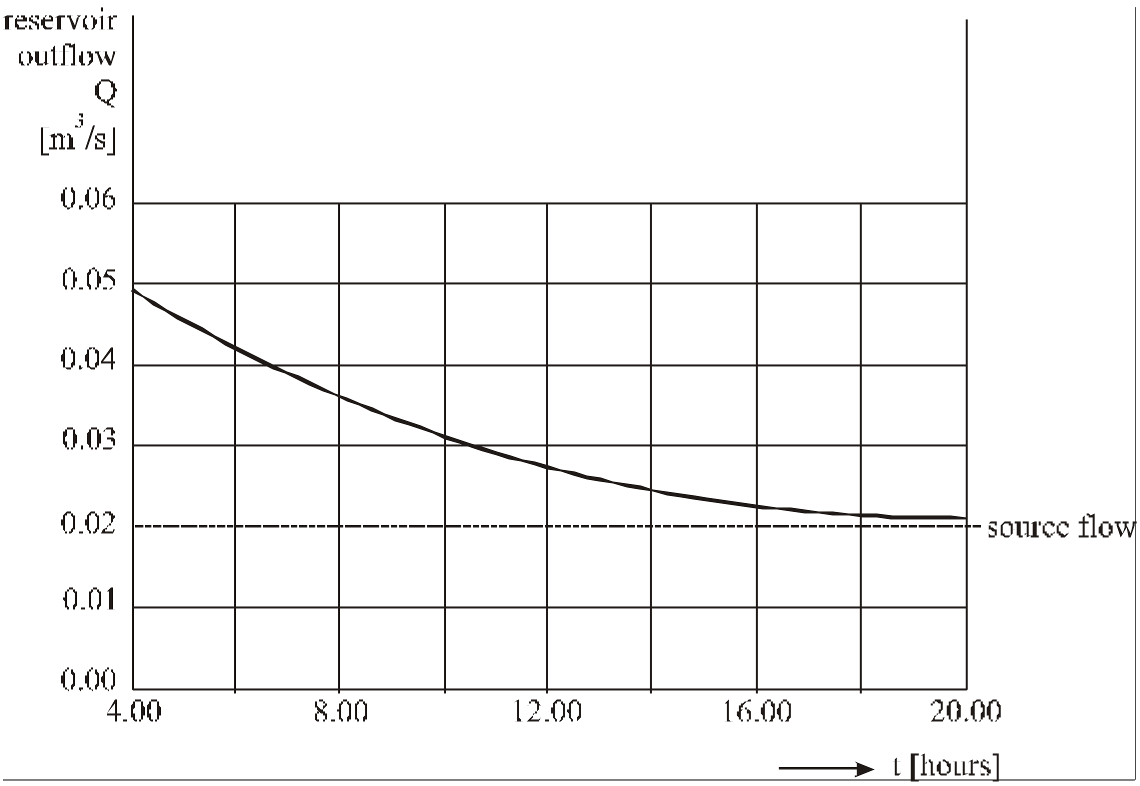
Arithmetic example
Given: t_f =16 hours; constant source flow Q_{in}: 0.020 m3/s; C= 0.6 (ILRI *et al.*, 1978: 296)

It has to be noted that Eq. (4) is highly sensitive to changes in x and h_{min}

After some iterations the combination of h_{max} =1.00 m, h_{min} =0.18 m and x = 0.0425 results in a surface area of the reservoir equal to ab= 702 m2 and a diameter of the orifice equal to 0.15 m with given Q_{in} and t_f . This results in a reservoir outflow between Q_{max} = 0,049 m3/s and Q_{min} = 0.021 m3/s.

The outflow pattern as a function of time is graphically represented in the Graph below.

Outflow pattern from a reservoir with permanent inflow



Appendix V Outflow Pattern from a Reservoir with no Inflow During the Day Period. Calculation of Reservoir and Orifice Dimensions

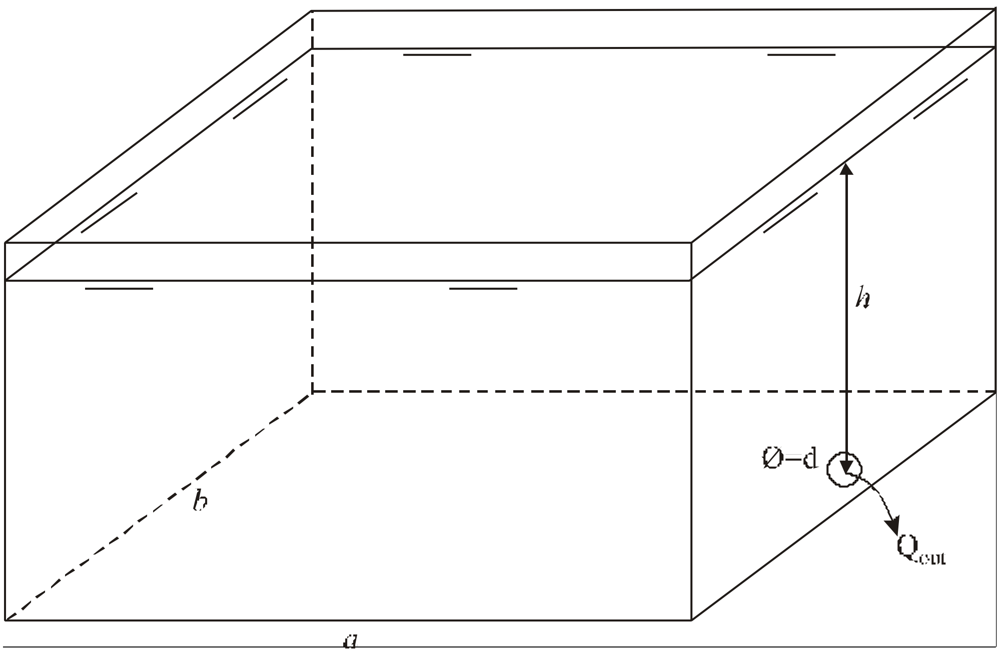
For *outflow conditions and outflow equation* see Appendix IV.

Analysis

It is assumed that during the daytime (4.00 a.m. – 8.00 p.m.) while the reservoir is emptying, the source flow does not pass through the reservoir but goes directly to the main irrigation canal. Then the channel flow is the sum of the varying reservoir outflow and the constant source flow. Reservoir outflow varies between Q_{max} at t=0 and Q_{min} at $t=t_f$.

Volume of stored water in a rectangular reservoir (a*b) at t: V=abh(t) (see Figure below)

Reservoir with no inflow during the day period



Q_{out}=-dV/dt= -abdh/dt= C*A* $(2gh)^{0.5}$. It follows that: dt = (ab/CA)$(2gh)^{-0.5}$ dh

t = ∫ -(ab/CA)$(2gh)^{-0.5}$dh = (2ab/CA)$(2g)^{-0.5}$ *$h^{0.5}$ + K

It follows that: $h^{0.5}$ = (K-t)(CA/2ab)$(2g)^{0.5}$ and Q(t)= (K-t)($2gC^2A^2$/2ab) Equation (1)

Note that in Equation (1), *Q is a linear function of t*.

Boundary conditions:

t= 0 Q=Q_{max} = CA $(2gh_{max})^{0.5}$, it follows that K = (2ab/CA)$(2g)^{-0.5}h_{max}^{0.5}$

and Equation (1) becomes: $Q(t)= \{ (2ab/CA)(2g)^{-0.5} h_{max}^{0.5} - t\}(2gC^2A^2/2ab)$
for $t= t_f$ $\quad Q_{min} = CA(2gh_{min})^{0.5} = CA (2gh_{max})^{0.5} - t_f (2gC^2A^2/2ab)$

or: $h_{min}^{0.5} = h_{max}^{0.5} - t_f (2g)^{0.5} *CA/2ab$

With $h_{min} = 2d$; $A= (pd^2)/4$; $C=0.6$ (ILRI *et al.* 1978: 296) and
$ab = Q_{in} *3600*(24- t_f)/(h_{max} - h_{min})$ Equation (2)
in which t_f in [hrs] en Q_{in} : source flow [m3/s]

It follows that:
$h_{max}^{0.5} = (2d)^{0.5} + t_f (2g)^{0.5} *0.6*(pd^2)/4 *(h_{max}-2d)/\{2*3600*Q_{in}*(24-t_f)\}$ Equation (3)

The Equations (2) and (3) give the interrelations between the various design parameters a, b, t_f, h_{max} and d, given $h_{min} = 2d$ and Q_{in}. It will depend on topographic conditions which is the range of possible values for a, b, d, t_f and h_{max}

Arithmetic Example

Let me illustrate the dimensioning of the reservoir and outflow orifice with an arithmetic example:

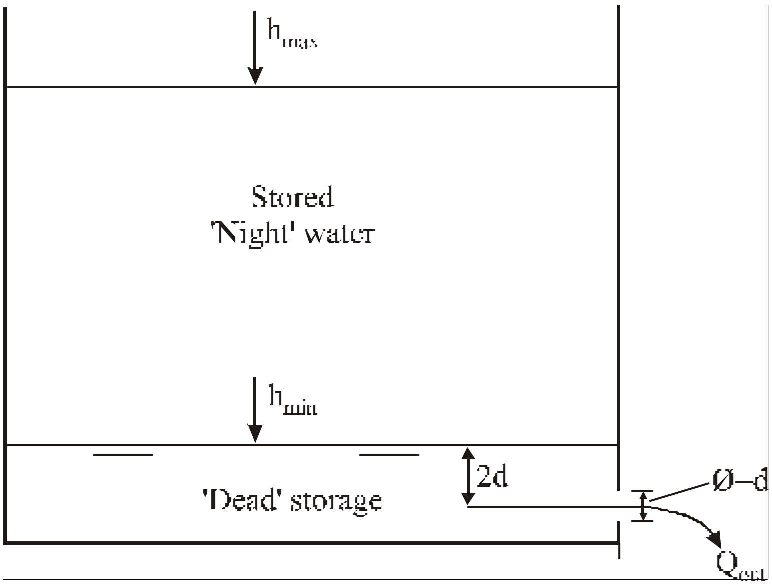
assume: $h_{max} = 1$ m and $t_f = 16$ hours; constant source flow Q_{in}: 0.020 m3/s
Storage needed above h=hmin: 8*3600*0.020=576 m3
discharge coefficient C=0.6 for a circular orifice (Bos, 1978: 296)
then Equation (3) is equal to:
$1= (2d)^{0.5} + 16*3600*4.43 *0.6*(pd^2)/4 *(1-2d)/(2*576)$

or: $1= (2d)^{0.5} + 104.33d^2 - 208.65d^3$

from this Equation, the diameter of the orifice can be calculated as d = 8.3 cm.

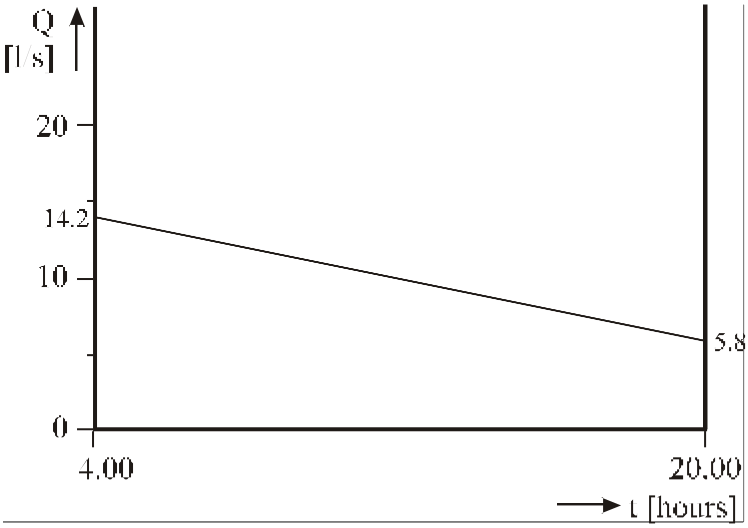
Q_{out} will vary between Q_{max} = 14,2 l/s and Q_{min} = 5.8 l/s
h_{min} =2d =16.6 cm . From Equation (2) follows that: ab = 690.6 m2, e.g. 20 m x 34.6 m
Needed 'dead' storage depth: ±3d = 24.9 cm which corresponds to a 'dead' storage volume of 172 m^3. Total required storage capacity: 576 + 172 = 748 m3 (for a cross section of the reservoir, see the Figure below)

Cross section of the night reservoir



For this arithmetic example the outflow as a function of t is graphically represented in the Figure below.

Linear reservoir outflow (Q) as a function of time (t)



Sensitivity analysis

According to ILRI *et al.* (1978: 295) the error in the discharge coeficient C for a well- maintained circular sharp-crested orifice, constructed with reasonable care and skill (see ILRI *et al.* 1978: 155) is expected to be in the order of one per cent.

In the following I will examine the consequences of an error of 0.01 in the value of the discharge coefficient C, applied to the arithmetic example above. If C=0.61 (an error of 1.7%) instead of 0.60 then Q_{max} =14.4 l/s and Q= 5.9 l/s when h_{min}=2d=16.6 cm. That is to say that stored night water (576 m3, assumed a source flow of 20 l/s during 8 hours) will be depleted in 15 h and 42 min. The extra outflow volume of the last 18 minutes necessary to complement the 16 hours will be 6.3 m3 that corresponds to a level 1cm below h_{min} and an inflow time of 6300/20 = about 5 min.

It can be concluded that these differences as a consequence of a small error (< 5%) in the discharge coefficient are irrelevant in irrigation practice. Moreover these differences can be minimised by a careful and coherent selection of the technical design variables of the reservoir and its operation (a, b, h_{min} , h_{max}) taking in account the local topography.

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List of Abbreviations

CPR	Common-Pool Resources
ct	*Conto*. 1ct = 1000 escudos (165 escudos = 1 US$ in 1989)
CU	Cattle Unit
DES	*Departamento de Economia e Sociologia* (of UTAD)
DRATM	Direcção Regional de Agricultura de Trás-os-Montes (Regional Directorate of Agriculture)
DGHEA	*Direccao Geral de Hidráulica e Engenharia Agrícola*
DSEA	*Divisão de Solos e Engenharia Agrícola* (Division of soils and rural engineering)
EEC	European Economic Community
EU	European Union
FEOGA	*Fundo Europeu de Orientação e Garantia Agrícola* (European Agricultural Guidance and Guarantee Fund)
FMIS	Farmer-Managed Irrigation System
IFADAP	*Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e Pescas*
INE:	*Instituto Nacional de Estatística*
JAR	Junta de Agricultores Regantes (Irrigator's council)
JCI	*Junta de Colonização Interna*
JF	*Junta de Freguesia* (Parish Council)
MRT	*Melhoria de Regadios Tradicionais* (Improvement of Traditional Irrigation Systems),
NRC	*Novo Regadio Colectivo* (New collective irrigation perimeter)
PAMAF	*Programa de Apoio à Modernização Agrícola e Florestal*
PDRITM	Projecto de Desenvolvimento Rural Integrado de Trás-os-Montes (Trás-os-Montes Integrated Rural Development Project)
PEDAP	P*rograma Específico de Desenvolvimento da Agricultura Portuguesa* (Specific Programme for the Development of the Portuguese Agriculture).
PRI:	P*equenos Regadios Individuais* (individual irrigation facilities)
SAU	*Superficie Agrícola Util* (actually used farm land)
SCOM	*Sala Colectiva de Ordenha Mecânica* (collective milking parlour).
UTAD	*Universidade de Trás-os-Montes e Alto Douro*
UA	*Unidade de Avialiação*
WAU	Wageningen Agricultural University

Glossary

'797' project: Investment subsidies in the framework of the EEC regulations 797/85 and 2328/91.

A vez: Allocation rule that states that as long as someone is irrigating, and therefore present on his field, he will be respected and other water users will have to wait for their turn.

Baldio: Stretches of common (moor)lands that were traditionally administered by village communities and used by the local population for pasturing their animals, collecting shrubs and fuel wood, stones etc. The commons are usually under the 'de facto' control of the residents of each hamlet or village, although in legal terms the land may actually owned and administered 'de jure' by a parish, municipal, or even a national administrative body.

Barrosã: Local breed in Barroso.

Cabaneiro: Cottager. Villager working for other farmers for payment in kind or wages. This term referred formerly both to the small *cabanas* or cottages of these villagers as well as to their manual digging labour (*cavar*) performed with hoes and picks.

Câmara Municipal: Town council. Local government body at the municipal level, above the level of the *Junta de Freguesia*, or Parish Council.

Casal: Household.

Chorume: Slurry or faeces plus urine and wash water. A type of liquid manure collected in large underground cesspools, an element of modern cowsheds.

Comissão de Baldios: Management commission of the commons.

Concelho: Municipality: the area administered by the *Câmara Municipal*. Each *concelho* or municipality consists of several *freguesias* or parishes.

Conselho: Literally: council. The word is used for the village councils held prior to 1976. This institution was called together to discuss questions and implement public works of common concern to all villagers.

Corga: Brook, small river.

Fonte: Water source.

Freguesia: Parish. Portuguese administrative division below the municipal level, formerly termed a *paróquia*. Several hamlets or villages usually comprise each rural parish.

Herdeiro: Heir or co-owner.

Junta de Freguesia: Parish Council. Local government body administering all of the hamlets and villages comprising a parish.

Lameiro: Permanent meadow.

Lameiro de erva: Small meadow plot which supplies during the whole year fresh grass.

Lavrador: Literally: ploughman, i.e. a farmer with enough land to sustain a pair of draught animals. The term suggests the English 'peasant' or 'cultivator' and refers to a form of relatively independent household production *not* involving wage labour.

Levada: Irrigation canal.

Mina: Gallery, horizontal tunnel dug into the mountains capturing groundwater.

Nascente: Spring.

Pedra de engenho: Self-starting siphon built in a reservoir.

Poça: Unlined reservoir, pool.

Poço: Shallow well.

RAM: Readily available moisture in the rootzone, which represents the moisture that can be taken up without affecting crop yield (the sensibility to increasing water stress is taken into account).

Rega de Lima: Irrigation of permanent meadows.

Regadio Tradicional: Traditional irrigation system. *Regadio Tradicional* is the Portuguese equivalent for FMIS.

Rego do povo: Collective irrigation system, literally: the people's canal.

Ribeiro: Small river.

Soil water depletion: Depleted water below field capacity calculated over the rootzone.

TAM: Total available moisture in the rootzone (water hold by the soil between field capacity and wilting point).

Terra Fria: 'Cold' Land. Geographical term referring to the Northern, more isolated part of Trás-os-Montes, stressing the region's mountainous terrain and cold climate.

Terra Quente: 'Hot' Land. Geographical term referring to the Central and Southern parts of Trás-os-Montes, stressing this region's lower plains and warmer climate.

Veiga: Area with intensive cultivated plots, normally irrigated.

Vizinho: Literally: neighbour. The habitants which are acknowledged as natural of the village and integrated in the social organisation of the village.

Summary

This book discusses an example of skill-oriented technology, located in the Trás-os-Montes region in Northern Portugal. Skill-oriented technologies, characterised by the combination of relatively *simple* instruments and *highly sophisticated* knowledge to operate these instruments, represent, at first sight, a reference to the past, at least in Europe. In current opinions reigning within state apparatuses and scientific circles, it is precisely these technologies that need to be replaced in order to modernise the agricultural sector. This book develops the thesis that there is considerable potential entailed in skill-oriented technologies, here embodied in Farmer-Managed Irrigation Systems (FMIS), which can be developed further.

Trás-os-Montes has an important farmer-managed irrigation sector. Farmers constructed, managed, maintained and improved their systems over the centuries without external intervention (in Portugal they are called traditional irrigation systems). This poses the question of the functioning of these systems, the context they are embedded in and the role of irrigation in farming. However, during the last decades the context (as a consequence of emigration, entrance of Portugal into the EU etc.) in which they are operating is changing profoundly. Related to these changes development projects have been introduced which stimulated new farming development patterns. This raises the question of the requirements of these new farming patterns related to irrigation practices compared to traditional farming patterns. The change in context also raises the questions of how farmer-managed irrigation is developing, how the irrigation systems are adapting to new circumstances, how public irrigation interventions could be characterised and what is the potential for the improvement of the Farmer-Managed Irrigation Systems. In a nutshell, these are the questions which are discussed in this book.

Chapter 1 describes the *theoretical key concepts* which are used to order and interpret the empirical reality of farmer-managed irrigation in Trás-os-Montes. Four interrelated key concepts are used to understand the functioning of FMIS: skill-oriented technologies, institutions, transaction costs and capital. First, in any labour or production process a certain relation exists between artefact, knowledge and technology. It is only through the required knowledge that an artefact is turned into a technique or technology to set into motion a particular process of production. In skill-oriented technologies we are faced with relatively simple instruments (a rudimentary irrigation infrastructure) that are used with far-reaching and detailed local knowledge that takes the conditions, goals, context and particularities of the concerned labour proces (irrigated agriculture) into account. Related to the development of technology is the *crafting of institutions*, that is the process of designing and developing working rules that participants understand, agree upon, and are willing to follow (Ostrom 1990). The term 'crafting' emphasises the skillful and ongoing nature of the institutional design process. A set of working rules must be place and time specific, internal coherent, shared knowledge and also meet the condition that they can be monitored and enforced in an effective and efficient way. These characteristics are inseparable elements. *Only in this way rules provide stability of*

expectations. The costs related to rule-making, coordination, monitoring and enforcement of the rules-in-use are called *transaction costs*. The lower the transaction costs, the more effective working rules are. The search for low transaction costs by making working rules simple (however they may seem complicated and strange at first sight) and easily controllable is a fundamental characteristic of FMIS in Trás-os-Montes. Another important concept is *capital*. The development of FMIS, or more generally, irrigation development, can be considered as the building up of capital. Any irrigation system can be viewed as a unique combination of physical (infrastructure), human (skills) and social (working rules) capital. The match of these elements, internally and with the context in which irrigation take place ('are they in line?') determines the sustainability and performance of an irrigation system. A 'high-tech' irrigation system could function highly suboptimally when rules and skills are not mutually adjusted to this technology and the context it is embedded. In the same way a 'low-tech' irrigation system in combination with appropriate rules and skills could achieve a remarkable efficiency in attaining the objectives for which they have been created. FMIS in Trás-os-Montes are an outstanding example of low-tech but highly efficient and effective systems.

Yet, right at this moment the very *continuity of FMIS* seems to be at stake. Basically this comes down to two phenomena. The first is that in the course of the centuries, labour was abundantly available within the agricultural systems of Trás-os-Montes and consequently, the availability of labour was hardly any restriction as far as the construction, management, maintenance and consolidation of irrigation systems was concerned. Precisely at this point there has been a dramatic change: labour became a scarce resource, principally due to the enormous migration flux to Western Europe since the end of the 1950s. The above-mentioned scarcity of labour, the crisis in agriculture, the opportunities and perspectives outside the agricultural sector are affecting the sustainability of irrigation systems. This is manifested in different and contradictory ways. Some FMIS are already abondened, others are in decay. Sometimes their water sources have dried up as a result of private water development. Other systems are more and more characterized by *stagnation* and an *involutionary process* of perfectioning and inward overelaboration of details (Geertz, 1963). This makes it more difficult to forge a qualitative transformation of the functioning of these systems.
The second problem related to the continuity of FMIS is more or less introduced from the outside. That is that the agricultural sector of Trás-os-Montes and Barroso in particular has increasingly become the object of outside interventions aiming at overall *modernization*. New farming patterns are stimulated that will need much more irrigation water, precisely in the summer period when water is most scarce. This clashes diametrically with the nature of actual irrigation practices.

In the typical analysis underpinning modernisation programmes the locally existing agricultural systems are, in accordance with the well-known Schultz thesis (1964), considered 'efficient but poor'. It is recognised that farmers make the best of the existing technical possibilities (as for instance embodied in existing irrigation systems). But they are poor at the same time: the 'technical ceiling' does not allow for anything more. Hence, in the end there is just one solution, that is to *replace* the existing resources and technologies with other, more productive ones. The central question of course is whether this modernisation approach is the only way out. Or is an alternative development strategy possible, that is a strategy that builds upon rather than marginalises the existing FMIS? Could FMIS be redesigned based on their own logic of functioning?
In Trás-os-Montes, especially in the Barroso area, contrasting agricultural development patterns are encountered, with different demands on water and irrigation technology. These different patterns may

be related to the concepts of exogenous vs. endogenous development. Exogenous development is based on an introduced set of external elements or a specific technological model. Endogenous development, rather, builds on existing resources and practices (van der Ploeg et al, 1994). The differentiation within agriculture, which is clearly linked with differentiated irrigation practices allowed to make a comparative empirical study of these different 'technological trajectories'.

Chapter 2 provides a detailed overview of the importance of FMIS, the elements which are crucial in the functioning of FMIS and the context in which they are embedded. The *importance of FMIS* in Portugal is reflected in the areas served by them which in 1979 amounted to 550,000 ha or 83 per cent of the total irrigated area in continental Portugal. Also in Trás-os-Montes more than 1000 FMIS have been identified covering about 40,000 ha. They are concentrated in two agro-ecological zones: the Mountains and the High Valleys. Together they constitute the research area. Within the research area there is a large diversity in ecological conditions, farming systems and irrigation potential.

Farming is characterised by smallholdings divided into numerous, dispersed plots. Farming systems are not specialised: a combination of products, both agricultural and livestock, satisfies diverse household needs. At the same time, farmers use the variety of physical conditions to reduce risks and to make optimal use of the present farming resources. A fundamental natural farming resource in Tras-os-Montes, particularly in the mountain areas are the commons or *baldios*. They are used for pasturing, collecting firewood and raw material for the preparation of cattle beds and organic manure. Farming households are interlinked by multiple relations of mutual dependence. Through these reciprocal relation-ships farmers mobilise and exchange resources. In the last decades pluriactivity is becoming more and more important. For many, agriculture has turned into a complementary activity in which production is mainly for household food needs.

Irrigation is practised throughout the year, both in summer and in winter. In the dry summer arable plots with maize and potatoes and home gardens with vegetables are irrigated. Irrigation in winter (for protection against frosts and manuring practice) and spring (for rapid regrowth) is applied to permanent meadows (*lameiros*), especially in the Mountains. These *lameiros* are a fundamental pillar of local farming systems as a main source of cattle feed in the whole year (pasturing) but particularly in the winter (hay). The management, the diversity in use and the irrigation of *lameiros* require a detailed knowledge of local field conditions and constitutes an outstanding example of skill-oriented farming technology in Trás-os-Montes. The same is valid for *field irrigation practices* and methods. Farmers apply almost all irrigation water by surface methods. It is found that field irrigation in summer is highly efficient with hardly application losses. The high labour input is another crucial characteristic of summer irrigation practices. The nature of *lameiro* irrigation is diametrically opposed to that of summer irrigation. Irrigation of *lameiros* is labour-extensive, irrigation canals and the field irrigation method (a variant of contour ditch irrigation) are suitable respectively to transport and to spread large quantities of water.
Generally, a multitude of water sources (surface water and groundwater) and irrigation facilities exists within the village domains. Hydrologic characteristics include a high *variability* of water flows during the agrarian calendar and a high *interconnectivity* of water sources. The irrigation systems and networks consist of different water sources scattered in the territory of the village, reservoirs, canals and fields, in different ways interconnected which at first sight give a chaotic impression. Interwoven

with this complex interrelated irrigation infrastructure is farmer's access to irrigation water under different property regimes. The contribution of these schemes to the overall water availability at farm level is specific for each farmer.

The management of FMIS is characterised by very low transaction costs. The driving force behind the daily functioning of the systems is the own interest of the individual water users to obtain the water they are entitled to. This is self-evident and leads to a nearly automatic control and enforcement of the rules. It is *the sharing of a scarce resource* that explains the logic behind the functioning of the systems. However, within this logic and depending on the socio-economic and physical context in which the irrigation systems are embedded, they operate in quite diverse ways.

The diversity of functioning of FMIS is clearly related to three strategic, interrelated *key elements*: water availability, water allocation and water distribution. These elements and their interrelationships are flexible during the agrarian calendar.
Water allocation may be defined on different grounds. Shares may be expressed in terms of time, or in surface area to be irrigated, or may not be clearly expressed at all. These bases provide grounds for the qualitative and quantitative assignment of water to right holders. A key question discussed in this book is the translation of abstract water rights (allocation) into real water flows (distribution). Working rules and mechanisms are basic to a correct translation of allocation in distribution. Two elements appear crucial: the *operation of reservoirs* and *compensatory/balancing mechanisms.* This last type of rules results in *the smoothing out of variations in flow* available for irrigation and the creation of average *equal conditions* for all users to obtain the water to which they are entitled.

The outcome of a changing context in which farming and irrigation are embedded, characterised by labour shortage, is a very heterogenous picture of the dynamics and stagnation in these irrigation systems. The majority of the systems continue to function and in some systems improvements are still made by the users. At the same time in many systems a clear tendency towards involution is taking place. On the other hand there is an unmistakable tendency towards the creation of individual irrigation facilities which leads towards the undermining of existing irrigation systems.

Chapter 3 presents two case studies of FMIS in Trás-os-Montes. In these case studies the most relevant aspects of the skill-oriented nature and complex functioning of FMIS in Trás-os-Montes are shown. A rudimentary physical infrastructure is compensated for by an elaborated system of water rights and a variety of rules to translate water allocation into water distribution. The case studies are specially intended to demonstrate the *locally constructed coherence* of the elements that have been discussed relatively in isolation from each other in Chapter 2.
Water is an essential means of production in Trás-os-Montes and as such subject to conflicts between people. Through specific working rules equal operational conditions for the water users with respect to variation of flows, timing of irrigation turns etc are created. In this way illegal use of water is constrained and conflicts between users are mimimized.

The case study of the communal irrigation system of Romainho focuses on the very complex water allocation pattern. Nearly all the allocation principles and some specific allocation rules are present at more levels. This actual pattern is the outcome of a long historical proces. The whole allocation schedule gives the impression of a tendency towards involution characterised by 'an increasing tenacity of the basic pattern, the gothic elaboration of technical and organisational detail, technical hairsplitting and unending virtuosity' (Geertz 1963:82). Although the potential for change exists, it is an open question if this will materialise. Maybe a recent improvement intervention was a missed opportunity to reorganize the system.

The case study of the communal irrigation system of Vila Cova shows how the functioning of the irrigation system is the outcome of a process of crafting working rules in which the diverse interests of local water users are brought *into line* with each other and the characteristics of the natural environment. This case study focuses on the complex translation of water allocation into water distribution. Detailed allocation of water in itself does not automatically result in distribution. In this translation many practical issues have to be solved. Examples are water losses in canals, the travel time of water in the canals, the sequence of irrigation turns and night irrigation which may all create inequalities in the opportunity of water users to actualise their share of the water. Working rules are necessary for this translation. These rules together create a continuously alternating pattern of water flows that at first glance seems chaotic but upon closer inspection is neatly ordered.

The first part of Chapter 4 considers the profound changes in the socio-economic conditions of the rural sector in Trás-os-Montes, commonly presented as the most depressed, marginalised region of Portugal. Historically, social stratification based on unequal access to land resources was sharp. Abject poverty was widespread. State interventions by the Salazar and Caetano regimes from the 1940s to 1974 affected the livelihood of many rural people. These unfavourable conditions combined with the strong need for industrial labour in West Europe, led to the massive *emigration* from the rural zones since the late 1950s. Such emigration had and still has a profound and contradictory impact upon the local communities and transformed the social and physical landscape in many aspects.

In the second part of Chapter 4, the diagnosis made by state agencies of the conditions of the rural sector in Trás-os-Montes and the development interventions based on this diagnosis is presented. Many of these interventions have been initiated and implemented in the framework of the Trás-os-Montes Integrated Rural Development Project (PDRITM) and the Specific Programme for the Development of the Portuguese Agriculture (PEDAP). These programmes aimed at the *modernisation* of the agricultural sector. Traditional agriculture in which crops and animal production are combined, had to be transformed into intensive and competitive animal husbandry farms. In order to attain this objective the program was focused on stimulating a development based on exogenous elements, introduced from outside. Such changes were not understood as merely incremental. They imply a drastic change in the socio-economic and technical organisation of farming. To strengthen this process, large credit facilities and subsidies were made available. In the *exogenous* development model, locally available resources are considered superfluous or even constraints for development, so that they need to be replaced. Only farms meeting minimum requirements, particularly in terms of size and availability of irrigation water could become involved in these programmes. These eligibility criteria excluded the majority of the farmers. This is at odds with the concept of *endogenous* development which builds on local resources, that is, the existing physical, human and social capital.

In the modernisation of the agricultural sector, PDRITM attributes a crucial role to irrigation.

This thesis focuses on the rehabilitation and improvement of traditional irrigation systems (MRT). The basic assumption of PDRITM and related programmes behind the improvement of traditional irrigation systems was the idea that this would create basic conditions for a modernisation of agriculture. This would in turn allow for increased fodder production and, consequently, intensified animal production. The specific objective of the MRT intervention was to increase the availability of irrigation water by reducing water losses through lining of canals and reservoirs.

In Chapter 5, the requirements related to irrigation of the induced exogenous agrarian development patterns represented by the farming style of the '*modernisers*' are analysed and compared to more endogenous agrarian patterns represented by the farming style of the '*intensifiers*'. To this end the farm accountancy data of two categories of farmers in the mountain area of Barroso representing these contrasting patterns were used. With the help of a constructed model, relationships between the use of irrigation water and farming characteristics as well as between the use of irrigation water and the technical-economic results of these groups were analysed. Main findings are:

- The requirements of scarce irrigation water in the summer per cattle unit are much higher in the exogenous than in the endogenous pattern.
- The input/output relations in terms of economic returns per unit scarce irrigation water are much more efficient within the endogenous pattern.

These findings show that the contrasting farming patterns in terms of exogenous and endogenous development embody highly relevant differences with respect to irrigation water use and mobilisation. The explanation lies particularly in the dependency of the 'modernisers' on additional irrigated land resources and new fodder crops like silage maize and temporary meadows. Therefore, the availability of large amounts of water in the summer period when resources are most scarce, is a necessity in the realisation of this pattern. The resources need to be adapted to the new requirements. This requires high investments and/or a redistribution of available water resources at the expense of other farmers. The pattern of 'intensifiers', for its part, produces the necessary fodder for the winter period principally on the *lameiros,* irrigated outside the summer period when precipitation and irrigation water are abundant. During the summer period the *baldios* constitute the principal fodder source. The endogenous farming pattern is *resource-based*: water demand and irrigation practices are adjusted to the natural water supply. In the exogenous farming pattern, however, the balance between farm water demand and natural water supply has been disturbed. Hence, modernisation emerges here as containing a tendency towards counter-productivity as far as water as a scarce resource is concerned. In other words, in terms of valorisation of (scarce) local resources the specific endogenous pattern of the 'intensifiers' is clearly superior to the exogenous pattern of the 'modernisers'.

The demands for irrigation in the exogenous farming pattern are not limited to higher irrigation water requirements. The labour-intensive character of traditional irrigation practices clashes sharply with the shortage of labour which is the most limiting factor in the exogenous farming pattern. Irrigation practices (timing, frequency etc.) in the existent irrigation schemes are bound to traditional rules reflecting social agreements about the sharing of a scarce resource which often do not coincide with modernisation demands requiring a water supply corresponding to maximal crop production.
The optimal production of great quantities of modern fodder crops such as silage maize and temporary meadows requires a type of crop-based irrigation management and technology which at

the same time permits to save labour, for instance in the form of new application technologies and/or higher application flows. In turn, these requirements presuppose access to individual sources. Therefore, in the exogenous farming pattern there is a strong tendency to individualise access to water.

Theoretically the tendency to counter-productivity of water use contained in the exogenous farming pattern leading to higher water requirements might be remedied by a strong decrease in water losses and/or by an increase in water use efficiency. Chapter 6 explores whether this is the case and to which extent the MRT intervention could contribute to this. The MRT intervention aims at increasing the availability of irrigation water through the limitation of water losses. Therefore the expected increase of available irrigation water is crucial. The assumptions underlying the MRT intervention are examined, the expected results are compared with real outcomes and the effects of the MRT intervention at field level are considered.

The MRT programme was based on the following underlying assumptions. First, that in the traditional irrigation systems quite a lot of water was available. Second, that the efficiency of these systems is very low because of their rudimentary hydraulic infrastructure. Third, it was stated that the irrigation water is not used productively.
All these underlying assumptions proved incorrect. First, from water source measurements it can be concluded that the available water is grossly overestimated. Second, measurements of losses in irrigation channels show that the assumption of the occurrence of water losses in no way is a uniform phenomenon but strongly dependent on local hydrological conditions, other natural factors but also on working rules. In some irrigation systems, even gains of water have been measured in the direction of the flow! Further, it can be questioned in various cases if the canal losses are real losses. The hydrological situation in many villages is characterised by the occurrence of many small dispersed water sources that are interdependent. A water loss from one source may very well be a gain for another water source. In such cases lining has only redistrubitive effects. Conceptually these effects are similar to the redistribution of water which occur when traditional water sources dry up as a consequence of the installation of new individual water sources. *Whether these effects are desirable or not and for whom cannot be determined from technical rules alone*. The whole local context need to be taken in account.
The third assumption that water in these irrigation systems is not productively used has no empirical basis nor theoretical fundament. Maximum crop yield as a criterion is not suitable in these systems because in the summer irrigation water is scarce in relation to land. The optimisation of the production per unit water is the standard. This is shown by the general practice of underirrigation. So, contrary to the assumption of an inefficient or unproductive water use, this practice points to an efficient use of the scarce water. Moreover, irrigation based on the sharing of a scarce resource what from a narrow technical perspective is considered inefficient, can be the most optimal and sustainable from a farmer's management perspective. It is especially the low transaction costs and easy monitoring that make the difference. Flexibility and water use according to its value in these systems is embedded in the framework of the existing working rules and farming systems.
Furthermore for the most important irrigation practice, that is the irrigation of hay meadows representing 2/3 of the total irrigated area in the mountains, an efficient use is irrelevant because of the abundance of water in autumn, winter and spring. An inefficient use is even favourable because it contributes to the recharge of the groundwater aquifers.

Considering its impact in the field, the MRT intervention only marginally contributed to the production objectives of the PDRITM programme. A reconversion of traditional agriculture did not take place. For most farmers the MRT intervention generated positive albeit limited and heterogenous results. For them the MRT intervention principally meant a cheap upgrading of their systems.
The MRT as a standard intervention practice, aiming at reducing water losses through lining of irrigation channels, operated in a heterogenous, diverse environment. The effects should be understood as the outcome of the intersection of the standard intervention package with the existing multi-facetted diversity in the field (physical and socio-economic context, farming systems, water sources and availability, water allocation and distribution and dynamics etc.).

The increase in water availability as effect of intervention is generally limited. In practice, increases of the irrigated area have hardly been encountered. In many systems the crucial factor is the availability of water at source level but lining has no effect on the size and the regime (regularity and reliability) of the source flow. The MRT intervention does not create more water but redistributes existing water. Moreover, the MRT intervention is not relevant for *lameiro* (hay meadow) irrigation because outside the summer months water for irrigation is generally abundant.
At the level of productive changes the increase in water has hardly induced an increase of agricultural production, and especially of irrigated fodder for milk production as was foreseen. For the development of the exogenous farming pattern the MRT intervention has not brought substantially more water neither the new labour-saving technology and the closely interlinked reorganisation of space, nor changes in the management of the systems.
In general farmers have used the greater availability of water to improve the irrigation of traditional crops and to make traditional irrigation practices more flexible. Many farmers mention the reduction of the labour burden related to irrigation activities as the main result of the intervention.

Chapter 7 presents some ideas and approaches to improve irrigation interventions and to redesign FMIS. This contribution can be only very modest because irrigation cannot be a *panacea* for the whole of complex problems facing the (agrarian) development of Trás-os-Montes and other marginalised areas. Irrigation can only be a strategic element (interrelated with others) in an integrated approach to rural development. The premise that building upon and improving the local potential of human and natural resources is the basis for sustainable rural development is the point of departure in this study. Under this premise irrigation development is to be based on the potential enclosed in farmer-managed irrigation and the adaptation of the irrigation systems to a changing context. This is elaborated at three different levels.

In the first part of this chapter, the agrarian question in Trás-os-Montes and particularly in Barroso is re-examined. Therefore a comparison is made of the potential impact of the contrasting farming patterns of the 'modernisers' and the 'intensifiers' on resource use and employment. This comparison shows that extrapolated to a regional level (of Barroso) this means that the endogenous farming pattern –through the improved use of local resources- potentially offers more labour opportunities than the exogenous farming pattern, given the same labour income. Apart from the potential impact on employment and incomes, the farming pattern of the 'intensifiers' is based on the use and reproduction of local ecological conditions and natural resources which preserve and

maintain the landscape and physical environment. Moreover, low external input combined with higher output prices implies a higher local value added.
The exogenous pattern claims to increase farmers incomes by transforming farming and production conditions but there are different grounds for questioning the viability of the exogenous agrarian development patterns and their contribution to regional agrarian development in Trás-os-Montes. First, this type of farming is dependent on external input markets and output markets for bulk products. Second, exogenous development patterns fail to build on the strong points of traditional farming such as its ecological soundness and use of local resources. Third, current modernisation projects involve considerable transformation costs, both internally and beyond the boundaries of the individual farm. These costs are especially high in the so-called marginal or less-favoured areas. For the 'modern' farm, *an environment needs to be created in which it can develop*.
In conclusion, there is a considerable *potential* for increasing incomes and employment on a regional scale based on the development of the endogenous farming pattern of the 'intensifiers' and this is a crucial condition for preventing the further desertification and abandonment of the rural areas in Trás-os-Montes.

But the endogenous development approach has consequences for the most appropriate form of irrigation development and the external support to it, which is different from the exogenous approach. For a balanced rural development it is necessary that the diversity of farming is the starting point for a suitable policy of rural and agricultural intervention. But this reorientation need to overcome many obstacles and 'hindrances' to realise the *endogenous potential.* Only through the creation of interrelations between local practices and resources, production chains, social carriers, farming styles and the social organisation, an effective process of endogenous development will develop. They have to be brought 'into line'. Second, an increase of scale (labour objects/labour unit) requires specific labour-saving technology. A crucial support to increasing scale and labour productivity (production/labour unit) would be the design and development of a proper supply of technology adapted to local conditions.

The two contrasting farm development patterns have different implications for irrigation interventions. Incomes in the endogenous pattern of the 'intensifiers' depend only to a small extent on scarce summer water. The *baldios* (pasturing) and *lameiros* (hay and pasturing) are the basic fodder resources. The development of the exogenous pattern, however, is very much dependent on increases in scarce summer water and as this required water is hardly available within the existing irrigation systems, 'new' water need to be created.
In terms of desired irrigation development, as far as the endogenous farming pattern of the 'intensifiers' is concerned, it is possible to develop the existing practices within the existing irrigation systems. Two specific support actions in the sphere of irrigation to develop the potential enclosed in endogenous farming patterns have been identified. First, the expansion and intensification of irrigated hay *lameiros* in order to take away the most limiting factor for the number of cattle a farm can hold. Second, the revitalisation of farmer-managed irrigation systems in order to adapt them to a changed context characterised by labour scarcity.

In section two of Chapter 7, an alternative approach is presented to strengthen local irrigation development. Irrigation development does occur as a result of both individual and collective farmer's initiatives, but external agents may also play an important role in strengthening irrigated farming.

Building on local resources, development perspectives, farmers' knowledge and local dynamics, alternative intervention strategies are formulated which have the potential to improve actual institutional irrigation interventions. The most important are:

- Integration of irrigation interventions with local development perspectives.
- Defining the decision-making process as a *joint venture* of state agencies and local water users. Intervention has to support ongoing local dynamics and strengthening local initiatives, furnishing resources that are outside the reach of local actors. In that sense external assistance has a complementary character.
- Building upon farmers' *local knowledge* about the area, physical conditions and related irrigation practices. S*elective lining could be more efficient*, i.e. total canal losses might decrease more with the same costs if only crucial parts of the whole irrigation infrastructure in a village would be lined instead of one canal being lined completely.

In the third part of this chapter the redesign of FMIS is discussed. The development potential of FMIS and its translation into coherent technical and institutional design aimed at adapting the systems to the new context of rural society in Trás-os-Montes is central. The focus is how existing irrigation practices could be adapted to labour scarcity.

A concrete application is the redesign of the Vila Cova FMIS departing from the local context in which irrigation takes place and the most important problems mentioned by the water users. In detail is discussed which (technical) options and possibilities exist to adapt the Vila Cova FMIS to the changing needs of the users and the changing context characterized by labour scarcity building upon its actual functioning and underlying logic already described in Chapter 3. A correctly dimensioned night reservoir with simple operational requirements is the most obvious solution with the highest potential impact. It has the potential to resolve five interrelated problems at the same time: night irrigation will be eliminated, labour input in irrigation activities will be reduced, the water distribution pattern can be simplified, water losses in the canals could be diminished and the tail end will receive more water. From this case it can be concluded that there are strong *interrelationships* between the technical (infrastructural) and institutional (working rules) dimensions of an irrigation system. If one element is changed, it has repercussions on the functioning of the whole. The other elements that constitute the irrigation system need to be mutually adapted. Second, a suitable improvement plan must be drawn up starting from the *local situation and its opportunities*. Third, meaningful interventions will have to focus on the *changes in the context* in which farming and irrigation practices are taking place.

After the presentation of this specific improvement proposal a more general *repertoire* of the potential for redesigning FMIS is derived covering the diversity of systems. Labour scarcity is to be taken in account as one of the fundamental features to be resolved (at least partially) through the proposed intervention. The repertoire contains principally interventions with a labour-saving potential. The most important are:

* *The (re)construction of irrigation reservoirs*

The construction of a new reservoir must be accompanied by changes in water distribution (rules and practices) and changes in water allocation. The allocation of the inflow, the use (design and operation) of reservoirs and the distribution of the reservoir outflow are related to each other in specific ways in order to be mutually compatible. A reservoir with a linear outflow as function of

time, permitting a distribution of the outflow on basis of time shares, as a new technical option, has the potential of broadening intervention perspectives in FMIS. It can be used as a new intervention tool in various situations.
* *Substituting small reservoirs by larger capacity reservoirs*
Labour input could be considerably reduced and flexibility in labour input increased if existing reservoirs were amplified or new reservoirs constructed that have a larger capacity. Water distribution rules and water use practices need to be adapted accordingly. Particularly the combination of relatively large capacities reservoirs with a linear outflow pattern has a great potential for broadening the scope of intervention. Apart from the labour-saving potential these larger reservoirs have two additional advantages. First, the operation time of these reservoirs could be better adapted to the needs of pluriactive farmers. Another advantage is that the water flow is more concentrated reducing canal losses.
Apart from the flow characteristics of the water source(s), three *existing elements* are crucial in the actual functioning of Trás-os-Montes' FMIS. First, *water allocation*, which determines who has right to use the water and how these water rights or shares are distributed among the users. This element offers the necessary security for users to receive the share of the available water to which they are entitled. A second existing element is the *compensatory mechanisms.* In the translation of water allocation into water distribution in Trás-os-Montes systems, these mechanisms and rules are fundamental to equalising operating conditions and variations in streamflow . These compensatory mechanisms are a crucial, albeit underestimated, element in (re)designing irrigation systems. A third existing element is the *use of reservoirs*. In comparison with situations without reservoir, they make irrigation more efficient, both in restricting water losses (higher flows result in relatively less canal losses) and labour input.
The redesign of FMIS could be centered around these three basic elements. Reservoirs combined with compensatory mechanisms represent a promising potential to explore for the improvement and adaptation of actual irrigation systems to a context of labour scarcity. A rough estimate of this labour-saving potential is made on the level of an 'average' FMIS, on the regional level and on a national scale.

It is shown that this new type of interventions can be based on already existing elements in the systems and on the actual logic of functioning of these systems. This supports the central thesis in this book stating that there is a considerable potential entailed in the skill-oriented technologies, embodied in FMIS, which can be developed further. This new type of interventions maintain the fundamental characteristics of FMIS, for instance the sharing of scarce water by means of water rights and low transaction costs, but at the same time allowing for more efficient and labour saving irrigation practices, particularly adapted to the actual context of labour scarcity.
However, potential is one thing, whether this potential could be realised is another. In some cases the unmistakable tendency towards the creation of individual irrigation facilities will be dominant, hinder the realisation of interventions in FMIS and even undermine FMIS. For certain categories of farmers, particularly those who have access to capital grants and subsidies, investing in the development of individual sources is an easier way than contributing to changes in FMIS. In other cases the status quo and vested interests will be so strong that stagnation and tendencies to involution will continue. On the other hand, external actors (State agencies, engineers etc.) could support the realisation of this potential by collaboration, facilitation and supplying resources that are currently unavailable. But this support will have to depart from the situation as it is and not from an assumed or 'virtual' reality.

Resumo

Este livro debruça-se sobre um exemplo de tecnologia baseada em conhecimentos acumulados e experiências locais (*skill-oriented tecnology*), localizado na região de Trás-os-Montes, no Norte de Portugal. *Skill-oriented tecnology* caracterizado por uma combinação de instrumentos relativamente *simples* com um conhecimento *altamente sofisticado* para operar esses instrumentos, representa, à primeira vista, uma referência ao passado, pelo menos no que se refere à Europa. Em opiniões predominantes no âmbito dos aparelhos de estado e dos círculos científicos, são precisamente estas tecnologias que necessitam de ser substituídas com o objectivo de modernizar o sector agrícola. Neste livro defende-se a tese de que existe um potencial considerável vinculado a s*kill-oriented tecnology*, neste caso incorporado nos regadios geridos pelos agricultores, que poderá ser objecto de desenvolvimento.

Trás-os-Montes possui um importante sector de regadio gerido pelos agricultores, que construíram, manejaram, mantiveram e melhoraram os seus sistemas ao longo dos séculos sem intervenção externa. Em Portugal este tipo de regadios são chamados Regadios Tradicionais (RT). Aqui se levanta a questão do funcionamento destes sistemas, o contexto no qual os mesmos estão implantados e o papel desempenhado pela irrigação na agricultura. Contudo, durante as últimas décadas o contexto nos quais os mesmos funcionam (como consequência da emigração, da entrada de Portugal na UE, etc.), tem sofrido mudanças profundas. Relacionados com estas mudanças têm sido introduzidos projectos de desenvolvimento que incentivaram novos padrões de desenvolvimento agrícola. Isto levanta a questão dos requisitos destes novos padrões agrícolas relacionados com as práticas de rega, comparativamente aos padrões agrícolas tradicionais. A mudança no contexto também levanta a questão de como se estão a desenvolver as práticas de rega, como os sistemas de regadio se estão a adaptar a novas circunstâncias, como as intervenções públicas de irrigação podem ser caracterizadas e qual é o potencial existente para a melhoria dos Regadios Tradicionais. De forma resumida, são estas as questões que são discutidas neste livro.

O Capítulo 1 descreve os *conceitos chave* que são utilizados para ordenar e interpretar a realidade empírica dos sistemas de rega geridos pelos agricultores em Trás-os-Montes. Utilizam-se quatro conceitos chave inter-relacionados de forma a se poder compreender o funcionamento dos regadios geridos pelos agricultores, a saber, *skill-oriented technology,* instituições, custos de transacção e capital. Em relação ao primeiro conceito, em qualquer processo de trabalho ou de produção existe uma certa relação entre artefacto, conhecimento e tecnologia. É apenas através do conhecimento requerido que um artefacto se torna numa técnica ou tecnologia, para pôr em movimento um processo de produção específico. No caso de s*kill-oriented tecnology*, encontramo-nos perante instrumentos relativamente simples (p.e. uma infra-estrutura rudimentar de regadio) que são utilizados com um conhecimento local pormenorizado e profundo que toma em consideração as condições, objectivos, contexto e particularidades do processo de trabalho em questão (agricultura

de rega). Relacionada com o desenvolvimento da tecnologia está o *enraizamento* ('crafting') *das regras referentes ao uso,* isto é, o processo de desenhar e elaborar regras de trabalho e uso que os participantes possam compreender, concordar e se disponham a seguir (Ostrom,1990). O termo 'enraizamento' enfatiza a natureza contínua e baseada no conhecimento e experiência local do processo de desenho institucional. Um pacote de regras de trabalho e de uso deverá ser específico em função do local e do tempo, apresentar uma coerência interna, evidenciar um conhecimento partilhado e satisfazer, igualmente, a condição de que pode ser monitorizado e imposto de modo eficaz e eficiente. Estas características constituem elementos inseparáveis. *Somente desta forma as regras referentes ao uso proporcionam estabilidade de expectativas.* Os custos relacionados com a elaboração das regras, a coordenação, monitoria e fortalecimento das regras referentes ao uso são chamados *custos de transacção ou de operação*. Quanto mais baixos são estes custos de transacção, tanto mais eficientes são as regras de uso. A busca de custos baixos de transacção, através da elaboração de regras de uso simples (embora à primeira vista possam parecer complicadas e singulares) e facilmente controláveis constitui uma característica primordial dos RT em Trás-os-Montes. Outro conceito importante é *capital*. O desenvolvimento dos RT, ou, de um modo mais genérico, o desenvolvimento de regadios, pode ser considerado como edificação de capital. Qualquer sistema de regadio pode ser encarado como uma combinação única de capital físico (infra-estruturas), humano (aptidões) e social (regras de trabalho e uso). A coerência interna destes elementos e o contexto no qual a rega se desenrola determina a sustentabilidade e desempenho de um sistema de regadio. Um sistema de regadio utilizando tecnologia avançada (*high-tech)* pode funcionar muito abaixo do seu potencial quando as regras referentes ao uso e os conhecimentos não se encontram adaptados mutuamente a esta tecnologia e ao contexto em que a mesma se encontra implantada. Da mesma forma, um sistema de regadio que utiliza uma tecnologia rudimentar (*low-tech)*, combinada com regras e conhecimentos adequados, pode atingir uma eficiência notável quanto ao alcance dos objectivos para os quais foi criada. Os RT em Trás-os-Montes constituem um exemplo marcante de sistemas *low-tech* mas altamente eficientes e eficazes.

No entanto, neste momento a *continuidade dos RT* parece estar em jogo. Basicamente, isto deriva de dois fenómenos. O primeiro é que, ao longo dos séculos, se verificou sempre uma disponibilidade abundante de força de trabalho dentro dos sistemas agrícolas de Trás-os-Montes e, consequentemente, a disponibilidade de força de trabalho praticamente nunca constituiu uma restrição no respeitante à construção, gestão, manutenção e consolidação dos sistemas de regadio. Precisamente, neste ponto registou-se uma mudança dramática: a força do trabalho tornou-se um recurso escasso, devido principalmente ao enorme fluxo migratório para a Europa Ocidental nos finais da década de 50. A supracitada escassez de força de trabalho, a crise na agricultura, as oportunidades e perspectivas fora do sector agrícola, estão a afectar a sustentabilidade dos sistemas de regadio. Tal manifesta-se de formas distintas e até contraditórias. Alguns RT já foram abandonados, outros encontram-se em declínio. Por vezes, as suas fontes de água secaram como resultado de exploração de novas fontes privadas de água. Outros sistemas cada vez se caracterizam mais por *estagnação* e um *processo de involução*. Este processo é caracterizado por um aperfeiçoamento e uma sobre-elaboração interna de detalhes (Geertz, 1963). Tal faz com que seja mais difícil forjar uma transformação qualitativa do funcionamento destes sistemas.

O segundo problema relacionado com a continuidade dos RT foi introduzido, em certa medida, a partir do exterior: o sector agrícola em Trás-os-Montes em geral e em Barroso em particular, tornou-se cada vez mais objecto de intervenções externas visando uma *modernização* global. Estimulam-se novos padrões de desenvolvimento agrícola que necessitam de muito mais água de rega, exactamente no período estival quando há mais escassez de água. Tal colide frontalmente com a natureza das práticas existentes de rega.

Numa análise típica subjacente aos programas de modernização, os sistemas agrícolas locais são considerados, segundo a tese de Schultz (1964), 'eficientes mas pobres'. Reconhece-se que os agricultores tiram o maior proveito das possibilidades técnicas existentes (como por exemplo, as incorporadas nos sistemas de regadio existentes). Mas ao mesmo tempo, estes são pobres. O *plafond técnico* não lhes permite mais. No fim, há apenas uma única solução, isto é *substituir* os recursos e tecnologias existentes por outros, mais produtivos. A questão central é, evidentemente, se esta abordagem inerente à modernização constitui a única saída. Ou existe uma possível estratégia de desenvolvimento alternativa, uma estratégia que toma como ponto de partida o potencial dos RT existentes em vez de os marginalizar? Pode-se redesenhar os RT, com base na sua própria lógica de funcionamento?

Em Trás-os-Montes, e especialmente em Barroso, existem padrões contrastantes de desenvolvimento agrícola, com exigências distintas quanto a água e à tecnologia de rega. Estes padrões distintos podem ser relacionados com os conceitos de desenvolvimento *exógeno* vs. desenvolvimento *endógeno*. O desenvolvimento exógeno encontra-se baseado num conjunto de elementos externos ou num modelo tecnológico específico. Por sua vez, o desenvolvimento endógeno assenta principalmente nos recursos e práticas existentes (Van der Ploeg *et al*, 1994). A diferenciação no âmbito da agricultura, que está nitidamente ligada com práticas de rega diferenciadas, permitiu elaborar um estudo comparativo empírico destas diferentes "trajectórias tecnológicas".

O Capítulo 2 proporciona uma panorâmica detalhada sobre a relevância dos RT, os elementos que são cruciais para o funcionamento dos RT e o contexto no qual os mesmos se encontram implantados. A *relevância dos RT* em Portugal reflecte-se nas áreas servidas pelos mesmos que, em 1979, se cifravam numa superfície de 550.000 ha, ou seja 83% da área total irrigada de Portugal continental. Foi identificado, igualmente, em Trás-os-Montes um número superior a 1.000 RT, cobrindo uma área de cerca de 40.000 ha e que se encontram concentrados em duas zonas agro-ecológicas: as montanhas e os vales sub-montanos, formando juntos a área aonde se realizou a investigação. Dentro da área de investigação existe uma grande diversidade de condições ecológicas, sistemas agrícolas e potencial de irrigação.

O sector agrícola em Trás-os-Montes caracteriza-se por pequenas explorações agrícolas, subdivididas em numerosas parcelas dispersas. As explorações não conhecem uma especialização: combinam diversos produtos, quer agrícolas, quer de produção animal, para satisfazer as necessidades dos agregados familiares. Ao mesmo tempo, os agricultores fazem uso da variedade de condições físicas de forma a reduzirem os riscos e conseguirem um uso máximo dos recursos agrícolas existentes. Em Trás-os-Montes e particularmente nas zonas de montanha, um recurso agrícola natural fundamental são os baldios, que são utilizados para pastagens, recolha de lenha e de matérias vegetais para a preparação das camas para o gado e estrume. Os agregados familiares agrícolas encontram-se interligados através de relações múltiplas de dependência mútua. Através destas relações recíprocas, os agricultores mobilizam e trocam recursos. Nas últimas décadas a pluri-actividade ganhou uma importância cada vez maior. Para muitos, a agricultura tornou-se uma actividade complementar na qual a produção se destina, principalmente, a satisfazer as necessidades alimentares dos agregados familiares.

A rega é praticada ao longo de todo o ano, tanto no Verão como no Inverno. Nos períodos estivais procede-se à rega das hortas e das parcelas com milho e batatas. A rega no Inverno (para a protecção contra as geadas) e na Primavera é aplicada nos prados permanentes (lameiros), especialmente nas zonas de montanha. Estes lameiros constituem um importante pilar dos sistemas agrícolas locais, na medida em que constituem a principal fonte de alimentação do gado durante todo o ano (pastos) e, particularmente, no Inverno (feno). O manejo, diversidade quanto ao uso e a rega dos lameiros, requer um conhecimento detalhado das condições locais de campo e constitui um exemplo notável de *skill-oriented tecnology*, em Trás-os-Montes. O mesmo se aplica aos métodos e às *práticas de rega.* Os agricultores aplicam quase toda a água de rega por gravidade. Constatou-se que a rega é altamente eficiente no Verão, quase não se verificando perdas de aplicação. O elevado *input de força de trabalho* constitui outra característica crucial das práticas de rega estival. A natureza da rega nos lameiros é diametralmente oposta à da rega estival – a rega praticada nos lameiros não utiliza muita força de trabalho, e os canais de regadio e o método de rega dos campos (regadeiras de nível) são adequados, respectivamente, para o transporte e dispersão de grandes quantidades de água.
De um modo geral, existe uma multiplicidade de fontes de água (água de superfície e água subterrânea) e infra-estruturas de regadio dentro da área da aldeia. As características hidrológicas incluem uma grande *variabilidade* de fluxos de água durante o calendário agrícola e uma elevada *interconexão* das fontes de água. Os sistemas e as redes de regadio são compostos por várias fontes de água espalhadas pelo termo da aldeia, reservatórios, canais e campos, interligados de diversas formas, o que, à primeira vista, dá uma impressão caótica. Entrelaçado a esta complexa e interligada infra-estrutura de regadio encontra-se o acesso do agricultor à água de rega, sob diferentes formas de propriedade. A contribuição destes sistemas no que respeita à disponibilidade total de água ao nível da exploração agrícola, é específica para cada agricultor.

A gestão dos RT caracteriza-se por custos de transacção muito baixos. A força motriz que subjaz o funcionamento quotidiano dos sistemas é o próprio interesse dos utilizadores individuais de água em obter a água a que têm direito. Tal é evidente e conduz a um seguimento e controlo quase automático das regras referentes ao uso. A *partilha dos escassos recursos de água* explica a lógica que se encontra por detrás do funcionamento dos sistemas. Contudo, dentro desta lógica e dependendo do contexto sócio-económico e físico no qual os sistemas de regadio se encontram implantados, os mesmos operam de maneiras bastante diferentes.

A diversidade quanto ao funcionamento dos RT encontra-se nitidamente relacionada com três elementos estratégicos chave e inter-relacionados: a disponibilidade, a atribuição e a distribuição da água. Estes elementos e as suas inter-relações são flexíveis durante o calendário agrícola.
A atribuição da água pode ser definida de diversas maneiras. Os direitos podem ser expressos em tempo ou em área de superfície a ser regada, ou até podem não ser expressos de forma nenhuma. Estes princípios constituem os fundamentos para uma atribuição qualitativa e quantitativa de água aos proprietários correctos. Uma questão chave discutida neste livro é de como ‘converter’ os

direitos abstractos de água (atribuição) em fluxos reais de água (distribuição). As regras e os mecanismos referentes ao uso são básicos para uma tradução correcta de atribuição para distribuição. Existem dois elementos cruciais: a *operação de reservatórios* e os *mecanismos compensatórios*. Este último tipo de regras resulta na mitigação *de variações quanto ao fluxo* disponível para rega e a criação de *condições médias iguais* para todos os utilizadores de forma a obterem a água a que têm direito.

O efeito provocado pela mudança do contexto no qual a agricultura e a rega se encontram implantadas e que se caracteriza por uma carência de força de trabalho, fornece uma imagem muito heterogénea da dinâmica e estagnação destes sistemas de regadio. A maioria dos sistemas continua a funcionar e em alguns destes são ainda feitas melhorias pelos seus utilizadores. Simultaneamente, em relação a muitos sistemas de regadio, está a verificar-se uma tendência nítida para involução. Por outro lado, existe uma tendência inequívoca para a criação de infra-estruturas de regadio individuais o que conduz a uma debilitação dos sistemas de regadio existentes.

O Capítulo 3 apresenta dois estudos de caso de Regadios Tradicionais em Trás-os-Montes. Nestes estudos de caso, mostram-se os aspectos mais relevantes dos RT quanto a s*kill-oriented tecnology* e ao seu complexo funcionamento. A infra-estrutura física rudimentar é compensada por um sistema elaborado de direitos quanto à água e uma variedade de regras que visam traduzir a atribuição da água para distribuição da água. Com os estudos de caso pretende-se demonstrar a *coerência erigida localmente* dos elementos que têm vindo a ser discutidos no capítulo 2, relativamente isolados uns dos outros.
A água constitui um meio de produção essencial em Trás-os-Montes e, como tal, encontra-se sujeito a desencadear conflitos entre os seus utilizadores. Através de regras de uso específicas, são criadas condições operacionais mais ou menos iguais pelos utilizadores da água, no que se refere à variação de fluxos, horários dos turnos de rega, etc. Desta maneira limita-se o uso ilícito da água e os conflitos entre utilizadores são minimizados.

O estudo de caso do sistema de regadio comunal de Romainho, coloca o seu enfoque no padrão muito complexo de atribuição da água. Encontram-se presentes, a mais níveis, quase todos os princípios de atribuição e algumas regras específicas de atribuição. Este padrão em vigor é a consequência de um prolongado processo histórico. Todo o esquema de atribuição confere a impressão de existir uma tendência para involução caracterizada por 'um aumento da tenacidade do padrão básico, a elaboração gótica do detalhe técnico e organizacional e uma virtuosidade infindável'(Geertz, 1963). Embora exista um potencial para mudança, mantém-se em aberto a questão se tal se irá materializar. Pode ser que uma intervenção recente de melhoria foi uma oportunidade perdida para reorganizar o sistema.

O estudo de caso do sistema de regadio comunal de Vila Cova mostra como o funcionamento do sistema de regadio é o resultado de um processo de enraizamento das regras de uso nas quais os diversos interesses dos utilizadores locais da água foram *alinhados* uns com os outros e com as características do meio ambiente natural. O estudo de caso coloca o seu enfoque na tradução complexa da atribuição de água para distribuição da água.
Uma detalhada atribuição da água não resulta, automaticamente, numa distribuição correcta da mesma. É necessário resolver muitos assuntos práticos que se colocam dentro desta tradução,

sendo disso exemplos, as perdas de água nos canais, o tempo de "viagem" da água nos canais, a sequência dos turnos de rega e da rega nocturna, aspectos que podem criar, todos eles, desigualdades quanto à oportunidade dos utilizadores de água para realizarem os seus direitos de água. Para se realizar esta tradução, são necessárias regras de uso. Conjuntamente, estas regras criam um padrão de fluxos de água continuamente alternado que, à primeira vista, parece caótico mas que, após uma inspecção mais aprofundada se encontra cuidadosamente ordenado.

A primeira parte do Capitulo 4 considera as mudanças profundas verificadas nas condições sócio-económicas no sector rural em Trás-os-Montes, apresentada geralmente como a região mais marginalizada de Portugal. Historicamente, a estratificação social baseada num acesso desigual aos recursos de terra era aguçada, verificando-se um alto nível de pobreza. As intervenções estatais durante os regimes de Salazar e Caetano, que vão desde os anos 40 até 1974, afectaram as condições de vida de grande parte da população rural. Estas condições desfavoráveis combinadas com uma necessidade aguda de mão de obra industrial na Europa Ocidental, conduziram a uma *emigração* massiva das zonas rurais, desde finais dos anos 50. Esta emigração teve, e continua ainda a ter, um impacto profundo e contraditório sobre as comunidades locais e transformou a paisagem social e física, em muitos aspectos.

Na segunda parte do capítulo 4 apresenta-se o diagnóstico feito pelas entidades estatais destas condições e as intervenções de desenvolvimento, baseadas nesta análise. Muitas destas intervenções foram iniciadas e implementadas dentro do quadro de trabalho do Projecto de Desenvolvimento Rural Integrado de Trás-os-Montes (PDRITM) e do Programa Específico de Desenvolvimento da Agricultura Portuguesa (PEDAP). Estes programas visam a *modernização* do sector agrícola. A agricultura tradicional, na qual se combina a produção agrícola e animal, tinha que ser transformada em explorações agrícolas de criação de gado, intensivas e competitivas. Para atingir este objectivo, o programa colocou o seu enfoque no estímulo de um desenvolvimento baseado em elementos exógenos, quer dizer, introduzidos a partir de fora. Tais mudanças não foram compreendidas como sendo simplesmente incrementícias. Em vez disso, elas implicam uma mudança drástica na organização sócio-económica e técnica da agricultura. Com o objectivo de fortalecer este processo, foram disponibilizados as grandes facilidades de crédito e subsídios. No modelo exógeno de desenvolvimento, os recursos disponíveis localmente são considerados como supérfluos ou até limitativos para o desenvolvimento, necessitando, pois, de ser substituídos. Apenas as explorações agrícolas que satisfazem os requisitos mínimos, particularmente no que se refere à sua dimensão e disponibilidade de água destinada a rega, podem ser envolvidos nestes programas. Estes critérios excluem a maioria dos agricultores. Tal opõe-se ao conceito de desenvolvimento endógeno que assenta nos recursos locais, quer dizer, no capital físico, humano e social existente.

O PDRITM atribui um papel crucial à irrigação com vista à modernização do sector agrícola. Esta tese coloca o seu enfoque na reabilitação e Melhoria dos Regadios Tradicionais (MRT). A premissa básica do PDRITM e de outros programas afins, que defendem a melhoria dos sistemas de regadio tradicionais, assenta na ideia que tal iria criar as condições básicas para uma modernização da agricultura. Por sua vez, isto permitiria um aumento da produção forrageira e, consequentemente, da intensificação da produção animal. O objectivo específico da intervenção MRT era de aumentar a disponibilidade de água de rega, reduzindo-se as perdas de água, através da impermeabilização de canais e de reservatórios.

No Capítulo 5 analisam-se as exigências quanto a irrigação dos padrões induzidos exógenos de desenvolvimento agrário, representados pela categoria de explorações agrícolas dos ‘modernizadores’, e compara-se com padrões agrários mais endógenos, pela categoria de explorações agrícolas dos ‘intensificadores’. Para tal fim foram utilizados os dados contabilísticos de duas categorias de agricultores na zona montanhosa de Barroso e que representam estes padrões contrastantes. Com a ajuda de um modelo construído, analisaram-se as relações entre a utilização de água de rega e as características agrícolas, assim como entre a utilização de água de rega e os resultados económicos-técnicos destes grupos. Os principais resultados a que se chegou, são:
- a quantidade necessária de água de rega, escassa no período estival, por cabeça normal de gado é muito mais elevada no padrão exógeno do que no padrão endógeno;
- as relações *input/output* em termos de rendimentos económicos, por unidade de água de rega, escassa, são muito mais eficientes dentro do padrão endógeno.

Estes resultados mostram que os padrões agrícolas contrastantes em termos de desenvolvimento exógeno e endógeno, incorporam diferenças muito relevantes com respeito à utilização e mobilização da água de rega. A explicação disto reside, especificamente, na dependência dos ‘modernizadores’ quanto a recursos adicionais de terra irrigada e de novas culturas forrageiras, como sejam o milho de ensilagem e os prados temporários. Por isso, a disponibilidade de grandes quantidades de água durante o período estival, quando os recursos são mais escassos, constitui uma necessidade com vista à realização deste padrão. Os recursos necessitam de ser adaptados às novas necessidades, o que exige grandes investimentos e/ou a redistribuição dos recursos de água disponíveis, a expensas de outros agricultores. Por seu lado, o padrão dos ‘intensificadores’ produz a forragem necessária para o período de Inverno, principalmente nos lameiros regados fora do período de estio, quando a água da precipitação e da rega são mais abundantes. Durante o Verão os baldios constituem a principal fonte de forragens. O padrão endógeno de desenvovimento agrário é *baseado nos recursos locais*: a procura de água e as práticas de rega são adaptadas à disponibilidade natural de água. No padrão exógeno de agricultura, no entanto, o equilíbrio entre a quantidade necessária de água para a produção agrícola e a disponibilidade natural de água foi perturbado. Por este motivo, a modernização emerge aqui como contendo uma tendência para uma contra-produtividade, no que concerne à água, na sua qualidade de recurso escasso. Por outras palavras, em termos de valorização de recursos locais (escassos), o padrão endógeno específico dos ‘intensificadores” é nitidamente superior ao padrão exógeno dos “modernizadores”.

As exigências de irrigação nos padrões exógenos de agricultura não se encontram limitadas a necessidades mais elevadas de água de rega. As práticas tradicionais de rega, com um carácter de trabalho intensivo, colidem frontalmente com a carência de força de trabalho, que constitui o factor mais limitante no padrão exógeno de agricultura. As práticas de rega (horário e frequência das regas, etc.) nos sistemas de regadio existentes estão ligadas a regras de uso que reflectem acordos sociais sobre a partilha de um recurso escasso, que muitas das vezes não coincide com as exigências de modernização, que requerem uma disponibilidade de água que corresponde a uma produção agrícola máxima. Uma produção máxima de grandes quantidades de culturas forrageiras modernas, tais como milho de ensilagem e prados temporários, requer um tipo de gestão e tecnologia de regadio baseado nas necessidades destas culturas que, simultaneamente, permite economizar trabalho, por exemplo sob a forma de novas tecnologias de aplicação e/ou fluxos mais elevados de aplicação. Por sua vez, estes requisitos pressupõem o acesso a fontes individuais. Por isso, no padrão exógeno de agricultura existe uma forte tendência para individualizar o acesso à água.

Teoricamente, a tendência para uma contraprodutividade no que se refere à utilização da água contida no padrão exógeno de agricultura que conduz a maiores necessidades de água, pode ser remediada por um considerável decréscimo de perdas de água e/ou um aumento quanto à eficiência na sua utilização. O Capítulo 6 explora se este é o caso e em que medida as intervenções MRT podem contribuir para tal. A intervenção MRT visava o aumento da disponibilidade de água de rega através de uma limitação das perdas de água. Por isso, o aumento previsto de água disponível para rega é crucial. Examinam-se as premissas subjacentes à intervenção MRT e comparam-se os resultados esperados com os efeitos reais da intervenção.

O programa MRT baseou-se nas seguintes suposições subjacentes: primeira – no sistema tradicional de regadio a disponibilidade de água é grande; segunda – a eficiência destes sistemas é muito baixa devido à sua infra-estrutura hidráulica ser rudimentar; terceira – foi afirmado que a água de rega não é utilizada de forma produtiva.
Todas estas suposições provaram ser incorrectas. Primeira, a partir de medições de caudais das fontes de água de rega pode-se concluir que a disponibilidade de água é muito sobrestimada. Em segundo lugar, as medições quanto às perdas de água nos canais de rega mostram que a suposição sobre a ocorrência de perdas de água não é um fenómeno uniforme, porém fortemente dependente das condições hidrológicas locais e de outros factores naturais, mas também das regras de uso. Em alguns sistemas de regadio, até se registou um aumento de caudal na direcção do fluxo! Para além disso, pode-se questionar em relação a vários casos se as perdas no canal são, realmente, perdas. A situação hidrológica em muitas aldeias caracteriza-se pela ocorrência de muitas fontes de água que são interdependentes. Uma perda de água proveniente de uma fonte pode constituir um ganho de água para uma outra fonte. Em tais casos, a impermeabilização apenas tem efeitos redistributivos. Conceptualmente estes efeitos são similares à redistribuição da água que ocorre quando as fontes tradicionais de água secam, como consequência da exploração de novas fontes de água individuais. *Não se pode determinar apenas através de regras técnicas se estes efeitos são ou não desejáveis e em relação a quem.* Tem que se tomar em consideração o contexto local na sua globalidade. A terceira suposição de que a água não é utilizada de forma produtiva nestes sistemas de regadio, não tem uma base empírica nem um fundamento teórico. O critério do rendimento máximo da produção não é adequado nestes sistemas visto que a água de rega durante o Verão é escassa em relação ao factor terra. O padrão é a optimização da produção por unidade de água. Tal é evidenciado pela prática geral de regas insuficientes que não enchem toda a zona radicular (*underirrigation*). Assim, contrariamente à suposição de uma utilização de água ineficiente e improdutiva, esta prática aponta para uma utilização eficiente de água escassa. Ademais, a rega baseada na partilha de um recurso escasso, que de uma perspectiva técnica estreita é considerado ineficiente, na perspectiva de gestão do conjunto de utilizadores pode ser a melhor e mais sustentável. São, em especial, os baixos custos de transacção e a facilidade de controlo que fazem diferença. A flexibilidade e a utilização de água em conformidade com o seu valor económico, nestes sistemas de regadio encontram-se inseridas no quadro das regras de uso e dos sistemas agrícolas existentes. Para mais, em relação à prática de rega mais importante, nomeadamente a rega dos prados de feno que representam 2/3 da área total irrigada nas zonas montanhosas, uma utilização eficiente é irrelevante na medida em que existe normalmente uma abundância de água durante o

Outono, o Inverno e a Primavera. Uma utilização ineficiente até é favorável na medida em que contribui para recarga da água subterrânea.

Considerando o seu impacto no terreno, a intervenção MRT apenas contribuiu de uma forma marginal para os objectivos de produção preconizados pelo PDRITM. Não se verificou uma reconversão da agricultura tradicional. Para a maioria dos agricultores a intervenção MRT gerou resultados positivos, ainda que limitados e heterogéneos. Para eles a intervenção MRT significou, principalmente, uma reabilitação barata dos seus sistemas de regadio.
A intervenção MRT que tinha como prática padrão de reduzir as perdas de água através da impermeabilização dos canais de rega, operou num meio ambiente diverso e heterogéneo. Os efeitos devem ser apercebidos como o resultado da interacção do pacote padrão de intervenção e a diversidade multifacetada no terreno (contexto físico e sócio-económico, sistemas agrícolas, fontes de água, atribuição e distribuição da água e sua dinâmica, etc.).

O aumento quanto à disponibilidade de água como efeito da intervenção, geralmente é limitado. Na prática, quase nunca se deparou com um incremento da área irrigada. Em muitos sistemas o factor crucial é a disponibilidade de água ao nível da fonte, mas a impermeabilização não produz qualquer efeito quanto ao caudal e ao regime hidrológico (regularidade e fiabilidade) da fonte. A intervenção MRT não cria mais água mas redistribui a água existente. Ademais, a intervenção MRT não é relevante para a irrigação dos lameiros pois, à excepção dos meses de Verão, a água de rega é, geralmente, abundante. Ao nível das mudanças produtivas o aumento de água praticamente não induziu a qualquer aumento da produção agrícola, em especial das culturas forrageiras de rega, tal como estava previsto. No que se refere ao desenvolvimento do padrão exógeno de desenvolvimento agrícola, a intervenção MRT não trouxe substancialmente mais água, nem uma tecnologia nova de economia de trabalho e a intimamente interligada reorganização de espaço, nem mudanças quanto à gestão dos sistemas.
De um modo geral, os agricultores utilizaram a maior disponibilidade de água para melhorarem a rega das culturas tradicionais e para tornar as práticas tradicionais de rega mais flexíveis. Muitos dos agricultores mencionam a redução da carga de trabalho relacionada com as actividades de rega, como sendo o principal resultado da intervenção.

O Capítulo 7 apresenta algumas ideias e abordagens tendentes à melhoria das intervenções de regadio e para o redesenho dos RT. Esta contribuição apenas pode ser muito modesta porque a irrigação não pode ser encarada como uma *panaceia* para a globalidade de problemas complexos com que se debate o desenvolvimento agrário em Trás-os-Montes e outras áreas marginalizadas. A irrigação apenas pode ser um elemento estratégico (inter-relacionado com outros) no seio de uma abordagem integrada de desenvolvimento rural. O ponto de partida neste estudo é constituído pela premissa que a base para um desenvolvimento rural sustentável assenta no desenvolvimento do potencial local dos recursos humanos e naturais. Assentando nesta premissa, o desenvolvimento da irrigação tem que se fundamentar no potencial encerrado nos RT e na adaptação dos sistemas de regadio a um contexto em mudança. Tal é elaborado a três níveis distintos.

Na primeira parte deste Capítulo reexamina-se a questão agrária em Trás-os-Montes e, particularmente, em Barroso. Deste modo é feita uma comparação do impacto potencial dos padrões de desenvolvimento agrário contrastantes representados pelos ‘modernizadores’ e pelos 'intensificadores', sobre a utilização e emprego dos recursos. Esta comparação mostra que, extrapolado a um nível regional (Barroso), tal significa que o padrão endógeno de agricultura – através da utilização melhor dos recursos locais – oferece, potencialmente, mais oportunidades de trabalho que o padrão exógeno de agricultura, suponhando o mesmo rendimento laboral. Para além do impacto potencial sobre o emprego e os rendimentos, o padrão agrícola dos "intensificadores" baseia-se na utilização e reprodução das condições ecológicas e dos recursos naturais locais, que preservam e mantêm a paisagem e o meio ambiente físico. Ademais, o baixo *input* externo combinado com preços mais elevados de *output*, implicam um valor acrescentado local mais elevado.

O padrão exógeno reivindica o aumento dos rendimentos dos agricultores através da transformação da agricultura e das condições de produção, mas existem diferentes razões para questionar a viabilidade dos padrões exógenos de desenvolvimento agrário e a sua contribuição para o desenvolvimento agrário regional transmontano. Em primeiro lugar, este tipo de agricultura encontra-se dependente de mercados externos de *inputs* e de mercados de produtos a granel Em segundo lugar, os padrões exógenos de desenvolvimento não se baseiam nos pontos fortes da agricultura tradicional, tais como sejam a sustentabilidade ecológica e a utilização dos recursos locais. Em terceiro lugar, os projectos de modernização actuais envolvem custos consideráveis de transformação, tanto internamente como para fora da exploração agrícola. Estes custos são particularmente elevados nas chamadas regiões marginais ou desfavorecidas. Para a exploração agrícola 'moderna', *é necessário criar um ambiente no qual esta se possa desenvolver*.
Como conclusão, existe um *potencial* considerável para aumentar os rendimentos e o emprego a uma escala regional, assentando no desenvolvimento do padrão endógeno de agricultura representado pela categoria dos 'intensificadores'. Tal é uma condição crucial para se evitar uma continuação da desertificação e do abandono das áreas rurais de Trás-os-Montes.

Todavia o desenvolvimento endógeno tem consequências em relação à forma mais apropriada de desenvolvimento da irrigação e do apoio externo à mesma, que difere da abordagem exógena. Com vista a um desenvolvimento rural balanceado é necessário que a diversidade existente na agricultura constitua o ponto de partida para uma política adequada de intervenção rural e agrícola. Mas esta reorientação necessita de ultrapassar muitos obstáculos e 'impedimentos' de forma a realizar o *potencial endógeno*. Apenas através da criação de inter-relações entre as práticas e os recursos locais, actores sociais, padrões de desenvolvimento agrícola e a organização social, se desenvolverá um processo eficaz de desenvolvimento endógeno. Estes elementos têm que ser "alinhados". Em segundo lugar, um aumento da escala de produção (objectos de trabalho/unidade de trabalho) requer uma tecnologia específica de economia de trabalho. Um apoio crucial para o aumento da escala de produção e a produtividade do trabalho consistirá no desenho e o fomento de uma provisão adequada de tecnologia adaptada às condições locais.

Os dois padrões de desenvolvimento agrícola contrastantes têm implicações distintas para as intervenções de regadio. Os rendimentos no âmbito do padrão endógeno dos 'intensificadores' apenas dependem de modo exíguo da água escassa disponível durante o Verão. Os baldios (para pastar) e os lameiros (para pastar e para a produção de feno) constituem os recursos forrageiros básicos. O desenvolvimento do padrão exógeno, encontra-se, contudo, muito mais dependente de um aumento da escassa água durante o Verão e, na medida em que esta água praticamente não se encontra disponível dentro dos sistemas de regadio existentes, é necessário criar-se 'nova" água.

Em termos de desenvolvimento de rega, no que diz respeito ao padrão endógeno agrícola de 'intensificadores', é possível desenvolver as práticas existentes, no seio dos sistemas de regadio existentes. Para tal foram identificadas duas acções de apoio na esfera da rega com vista ao desenvolvimento do potencial encerrado nos padrões endógenos agrários. A primeira é a expansão e intensificação dos lameiros de regadio para eliminar o maior factor limitante em relação ao número de cabeças de gado que uma exploração agrícola pode manter. A segunda é a revitalização dos sistemas de regadio geridos pelos agricultores com o objectivo de os adaptar a um contexto em mudança e que se caracteriza por uma escassez de força de trabalho.

Na segunda secção deste capítulo, apresenta-se uma abordagem alternativa visando o fortalecimento do desenvolvimento local de rega. O desenvolvimento de rega ocorre como resultado tanto de iniciativas individuais como de colectivas dos agricultores, mas os agentes externos também podem desempenhar um papel importante no reforço da agricultura de regadio. São formuladas estratégias de intervenção alternativas que encerram um potencial para melhorar as intervenções por parte das entidades estatais, assentando nos recursos locais, nas perspectivas de desenvolvimento, nos conhecimentos dos agricultores e nas dinâmicas locais. As mais importantes são:

- Integração das intervenções de regadio com as perspectivas de desenvolvimento local;
- Definição do processo de tomada de decisões como sendo uma *joint venture* das entidades estatais e dos utilizadores locais de água. Esta intervenção tem que apoiar as dinâmicas locais em curso e fortalecer as iniciativas locais, fornecendo recursos que se encontram fora do alcance dos actores locais. Neste sentido o apoio externo tem um carácter complementar.
- Basear-se no *conhecimento local* dos agricultores sobre a área em questão, condições físicas e práticas relacionadas com a rega. *A impermeabilização selectiva pode ser mais eficiente,* isto é, as perdas totais nos canais podem diminuir mais, sendo os custos os mesmos caso apenas as partes cruciais de toda a infra-estrutura de regadio numa aldeia sejam impermeabilizadas, em vez de impermeabilizar um canal inteiro.

Na terceira secção deste capítulo discute-se o redesenho dos RT. Aparece como central a questão do potencial de desenvolvimento dos RT e da sua tradução no desenho técnico e institucional coerente, visando uma adaptação dos sistemas de regadio ao novo contexto da sociedade rural em Trás-os-Montes. Coloca-se o enfoque em como as práticas de rega podem ser adaptadas à escassez de força de trabalho.

O redesenho do RT de Vila Cova constitui uma aplicação concreta, partindo do contexto local no qual a rega se desenrola e dos problemas mais prementes mencionados pelos utilizadores da água. Discute-se em pormenor quais opções e possibilidades (técnicas) existem com vista à adaptação do RT de Vila Cova, em relação a novas necessidades dos utilizadores e o contexto em mudança caracterizado por uma escassez de força de trabalho, desenvolvendo o seu funcionamento e a sua lógica subjacente, tal como já foi descrito no Capítulo 3. A solução mais óbvia e com um potencial de impacto mais elevado, consiste num reservatório nocturno dimensionado correctamente, com simples requisitos de operação. Insere em si o potencial para solucionar, simultaneamente, cinco problemas inter-relacionados: o regadio nocturno seria eliminado, o *input* de trabalho quanto às actividades de regadio reduzir-se-ia, a distribuição da água ficaria simplificada, as perdas de água nos canais poderiam diminuir e as parcelas na parte final dos canais receberiam mais água. A partir deste caso pode-se concluir que existem fortes *inter-relações* entre as dimensões técnica (infra-estrutural) e institucional (regras de uso) de um sistema de regadio. Caso se altere um elemento tal tem repercussões para o funcionamento de todo o sistema. Os outros elementos que constituem o sistema de regadio necessitarão de ser mutuamente adaptados. Em segundo lugar, tem que se elaborar um plano adequado de melhoria, partindo da *situação local e das suas oportunidades.* Em terceiro lugar, intervenções significativas terão que colocar o seu enfoque nas *mudanças verificadas no contexto* no qual a agricultura e as práticas de rega se encontram implantadas.

Após a apresentação desta proposta específica de melhoria, deriva-se um repertório mais geral do potencial para o redesenho dos RT, que cobre a diversidade dos sistemas. A escassez de força de trabalho tem que ser tomada em consideração na medida em que constitui uma das questões fundamentais a serem resolvidas (pelo menos parcialmente) através da intervenção proposta. O repertório contém principalmente intervenções com um potencial para economizar trabalho, sendo as mais significativas:

** A (re)construção dos reservatórios de regadio*

A construção de um novo reservatório tem que ser acompanhada com mudanças na distribuição da água (regras e práticas) e a atribuição da água. A atribuição do fluxo de entrada no reservatório, a utilização (desenho e operação) dos reservatórios e a distribuição do fluxo de saída de reservatório estão relacionados entre si de forma específica para serem compatíveis mutuamente. Um reservatório que tem um fluxo de saída com um decréscimo linear em função de tempo, permitindo a distribuição do fluxo de saída na base de direitos expressos em unidades de tempo, como uma nova opção técnica, apresenta o potencial de alargar as perspectivas de intervenção dos RT. Pode ser utilizado, em diversas situações, como novo instrumento de intervenção.

** A substituição de reservatórios pequenos por reservatórios com uma capacidade maior*

O *input* de trabalho pode ser reduzido consideravelmente e pode ser aumentado a sua flexibilidade, caso os reservatórios existentes possam ser ampliados ou se possam construir novos reservatórios que tenham uma maior capacidade. Simultaneamente, as regras de distribuição da água e as práticas da sua utilização necessitam de ser adaptadas. Principalmente a combinação de reservatórios com capacidades relativamente grandes e um fluxo de saída com um decréscimo linear, possui um grande potencial para ampliar o raio de acção da intervenção. Para além do potencial de economia de trabalho, estes reservatórios maiores apresentam duas vantagens adicionais. Primeiramente, o tempo de operação destes reservatórios pode ser melhor adaptado às necessidades dos agricultores pluri-activos. Uma outra vantagem reside no facto do fluxo de água ser mais concentrado, o que reduz as perdas de água nos canais.

Para além do regime do fluxo da(s) fonte(s) de água, há três *elementos existentes* que são cruciais para o funcionamento dos RT de Trás-os-Montes. O primeiro, a *atribuição da água,* que determina quem tem o direito para a utilizar e como é que estes direitos de água são distribuídos entre os utilizadores. Este elemento oferece a segurança necessária aos utilizadores para receberem a quota da água disponível à qual têm direito. O segundo elemento existente são os *mecanismos compensatórios.* Na tradução de atribuição da água para distribuição da água nos sistemas de regadio de Trás-os-Montes, estes mecanismos e regras são fundamentais para igualizarem as condições de operação e as variações no fluxo de água. Trata-se de um elemento crucial, embora subestimado, aquando do (re)desenho dos sistemas de regadio. O terceiro elemento existente é o *uso dos reservatórios*. Em comparação com situações em que não existem reservatórios, estes fazem com que a rega seja mais eficiente, quer no que respeita à restrição das perdas de água (fluxos maiores resultam em, relativamente, menos perdas nos canais) e de *input* de trabalho.

O redesenho dos RT pode centrar-se em torno destes três elementos básicos. Os reservatórios combinados com os mecanismos compensatórios representam um potencial promissor a ser explorado com vista à melhoria e adaptação dos sistemas de regadio existentes num contexto de escassez de força de trabalho. Uma estimativa aproximada deste potencial de economia de trabalho é feito ao nível dum RT 'médio', ao nível regional e à escala nacional.

Mostrou-se que este novo tipo de intervenções pode ser baseado nos elementos já existentes nos sistemas de regadio e na lógica de funcionamento desses sistemas. Isto apoia a tese central apresentada neste livro que afirma que existe um potencial considerável vinculado em s*kill-oriented tecnology*, incorporado nos RT, que se pode desenvolver mais. Este novo tipo de intervenções mantém as características fundamentais dos RT, por exemplo a partilha da água escassa por intermédio dos direitos da água e os baixos custos de transacção, mas permitindo, simultaneamente, práticas de rega mais eficientes e mais económicas de trabalho, adaptadas particularmente ao contexto concreto de escassez de força de trabalho.
Contudo, a existência de potencial é uma coisa; se este potencial pode ser realizado é uma outra. Em alguns casos a tendência inequívoca para a criação de facilidades de regadio individuais, impedirá a realização das intervenções nos RT acabando mesmo por os debilitar. No que se refere a certas categorias de agricultores, em especial os que têm acesso a capital e a subsídios, investir no desenvolvimento de fontes individuais constitui uma maneira mais fácil do que contribuir para mudanças nos RT. Em outros casos o *status quo* e os interesses adquiridos serão tão fortes que a estagnação e as tendências de involução continuarão. Por outro lado, os actores externos (entidades estatais, engenheiros, etc.) podem apoiar a realização deste potencial, através de uma colaboração, facilitação e fornecimento de recursos, que actualmente não se encontram disponíveis. Mas este apoio terá que partir da situação real e não de uma realidade suposta ou "virtual".

Samenvatting

In dit boek wordt een voorbeeld van '*skill-oriented*' technologie besproken. Dit voorbeeld betreft boerenirrigatiestelsels in Trás-os-Montes, gelegen in Noord Portugal. '*Skill-oriented*' technologieën, gekarakteriseerd door de combinatie van relatief eenvoudige instrumenten en geraffineerde kennis om deze instrumenten te gebruiken, lijken op het eerste gezicht een overblijfsel van het verleden, tenminste in Europa. In dominante opinies binnen staatsapparaten en wetenschappelijke kringen, zijn het precies deze technologieën die vervangen moeten worden om de agrarische sector te moderniseren. In dit boek wordt de stelling ontwikkeld dat er een aanzienlijk potentieel ligt opgesloten in '*skill-oriented*' technologieën, hier belichaamd in door boeren beheerde irrigatiestelsels, dat verder kan worden ontwikkeld.

Trás-os-Montes heeft een omvangrijke door boeren beheerde irrigatiesector. Boeren bouwden, beheerden, onderhielden en verbeterden hun stelsels gedurende de eeuwen zonder inmenging van buitenaf. Deze stelsels worden *Farmer-Managed Irrigation Systems* (FMIS) in het Engels genoemd. Deze term wordt hier aangehouden. Dit leidt tot de vraag naar het functioneren van deze stelsels, de context waarin zij zijn ingebed en de rol van irrigatie in de landbouwbeoefening. Echter, gedurende de laatste decaden is de context (als gevolg van emigratie, de intrede van Portugal in de Europese Unie etc.) waarin zij functioneren is sterk aan verandering onderhevig. Gerelateerd aan deze veranderingen zijn ontwikkelingsprojecten geïntroduceerd, die nieuwe ontwikkelingspatronen van landbouwbeoefening hebben gestimuleerd. Dit doet de vraag rijzen wat de eisen zijn die deze nieuwe landbouwpatronen aan irrigatiepraktijken stellen, vergeleken met traditionele landbouwpatronen. De verandering in context werpt ook de vraag op hoe boeren-irrigatie zich ontwikkeld; hoe FMIS zich aanpassen aan nieuwe omstandigheden; hoe publieke irrigatie interventies kunnen worden gekarakteriseerd en wat het verbeteringspotentieel is van deze irrigatiesystemen.

In Hoofdstuk 1 worden de sleutelconcepten besproken die gebruikt zijn om de empirische realiteit van boeren-irrigatie te ordenen en te interpreteren. Vier onderling gerelateerde concepten worden gebruikt om het functioneren van FMIS te begrijpen. Deze zijn: '*skill-oriented*' technologie, instituties, transactiekosten en kapitaal. Ten eerste, in ieder arbeids- of productie proces bestaat een bepaalde relatie tussen werktuig, kennis en technologie. Het is alleen door de vereiste kennis dat een werktuig, een techniek of technologie wordt om een specifiek productieproces in gang te zetten. In '*skill-oriented*' technologieën worden we geconfronteerd met relatief eenvoudige instrumenten (een rudimentaire irrigatie-infrastructuur). Echter die wordt gebruikt met een ver-reikende en gedetailleerde lokale kennis die rekening houdt met de condities, doeleinden, context en bijzonderheden van het desbetreffende arbeidsproces (geïrrigeerde landbouw).
Gerelateerd aan de ontwikkeling van de technologie is de '*crafting*' van instituties, dat is het proces van het ontwerpen en ontwikkelen van gebruiksregels die deelnemers begrijpen, waar ze het over

eens zijn, en die zij willen toepassen. De term '*crafting*' benadrukt het continue en '*skillful*' karakter van het institutionele ontwerp-proces. Een verzameling gebruiksregels moet plaats en tijd gebonden zijn en onderling coherent, het moet gedeelde kennis zijn en ook aan de voorwaarde voldoen dat zij kan worden gecontroleerd en afgedwongen op een efficiënte en effectieve manier. Deze karakteristieken zijn ondeelbaar. Alleen op deze manier verlenen regels stabiliteit in de verwachtingen. De kosten gerelateerd aan het maken van regels, coördinatie, controle en het afdwingen van de gebruiksregels worden transactie-kosten genoemd. Hoe lager de transactiekosten, hoe effectiever de gebruiksregels zijn. Het zoeken naar lage transactiekosten door het maken van eenvoudige gebruiksregels (hoewel ze op het eerste gecompliceerd en vreemd kunnen lijken), die gemakkelijk te controleren zijn is een fundamentele karakteristiek van FMIS in Trás-os-Montes.
Een ander belangrijk concept is kapitaal. De ontwikkeling van FMIS, of meer algemeen, irrigatie-ontwikkeling, kan worden beschouwd als het opbouwen van kapitaal. Ieder irrigatiesysteem kan worden gezien als een unieke combinatie van fysisch (infrastructuur), menselijk (vaardigheden) en sociaal (gebruiksregels) kapitaal. Het met elkaar in overeenstemming brengen van deze elementen, zowel intern als ook binnen de context waarin irrigatie plaats vindt, bepalen de duurzaamheid en het prestatievermogen van een irrigatiesysteem. Een '*high-tech*' irrigatie systeem kan zeer sub-optimaal functioneren, als gebruiksregels, vaardigheden en technologie niet onderling op elkaar en op de context waarin dit systeem is ingebed, afgestemd zijn. Op dezelfde manier kan een '*low-tech*' systeem in combinatie met geschikte regels en vaardigheden een opmerkelijke efficiëntie bereiken gelet op de doeleinden waarvoor zij gecreëerd zijn.

Toch, op dit moment lijkt het voortbestaan van de FMIS op het spel te staan. In wezen wordt dit verklaard door twee verschijnselen. De eerste is dat in de loop der de eeuwen arbeid overvloedig aanwezig was binnen de landbouwsystemen van Trás-os-Montes. Derhalve was de beschikbaarheid van arbeid nauwelijks een belemmering, voor zover het constructie, beheer, onderhoud en consolidatie van irrigatie systemen betrof. Precies op dit punt is er een dramatische verandering opgetreden: arbeid werd een schaarse factor, voornamelijk vanwege de enorme migratie stroom naar West Europa sinds het eind van de vijftiger jaren.
Het tweede probleem gerelateerd aan het voortbestaan van de FMIS, komt min of meer van buiten. Dat komt er op neer dat de landbouw sector in Trás-os-Montes en speciaal in Barroso in toenemende mate het voorwerp is geworden van externe interventies die een algehele modernisering tot doel hebben. Nieuwe landbouwontwikkelings-patronen werden gestimuleerd die meer irrigatie water nodig hebben, precies in de zomer periode wanneer water het meest schaars is. Dit botst lijnrecht met de aard van de bestaande irrigatie praktijken.

De voornoemde twee verschijnselen ondergraven de duurzaamheid van de irrigatiesystemen. Dat manifesteert zich op verschillende en tegenstrijdige manieren. Sommige FMIS zijn al verlaten, andere in verval. Soms zijn hun waterbronnen opgedroogd als resultaat van particuliere water exploratie. Andere systemen zijn meer en meer gekarakteriseerd door stagnatie en een involutionair proces van perfectionering en binnenwaardse overdrijving van details. Dat maakt het moeilijker om tot een omvorming in het functioneren van deze systemen te komen.

In de standaard-analyse die ten grondslag ligt aan moderniserings programmas worden de lokaal bestaande landbouwsystemen, in overeenstemming met de bekende these van Schultz (1964), als 'efficiënt maar arm' beschouwd. Het wordt erkend dat boeren het beste halen uit de bestaande technische mogelijkheden (bijvoorbeeld belichaamd in de bestaande irrigatie systemen). Maar zij zijn tegelijkertijd arm. Het 'technische plafond' staat niet méér toe. Dóór-redenerend is er uiteindelijk maar één oplossing, namelijk het vervangen van de bestaande hulpbronnen en technologieën door meer productieve. De centrale vraag is natuurlijk of deze moderniserings benadering daarvoor de enige manier is. Of is er een alternatieve ontwikkelings-strategie mogelijk die voortbouwt op de bestaande FMIS i.p.v. deze te marginaliseren? Kunnen FMIS worden hérontworpen uitgaande van hun eigen interne logica.

In Trás-os-Montes, speciaal in het Barrosa gebied, worden contrasterende landbouwontwikkelings patronen aangetroffen, met verschillende eisen met betrekking tot water en irrigatie-technologie. Deze verschillende patronen kunnen worden gerelateerd aan de concepten van exogene vs. endogene ontwikkeling. Exogene ontwikkeling is gebaseerd op geïntroduceerde externe elementen of een specifiek technologisch model. Endogene ontwikkeling bouwt voort op bestaande hulpbronnen en praktijken (van der Ploeg et al, 1994). De differentiatie binnen de landbouw, die duidelijk verbonden is met gedifferentieerde irrigatie praktijken maakte het mogelijk om een vergelijkende empirische studie te maken van deze verschillende 'technologische trajecten'.

Hoofdstuk 2 geeft een gedetailleerd overzicht van het belang van FMIS, de elementen die beslissend zijn in het functioneren van FMIS en de context waarin zij zijn ingebed. Het belang van FMIS in Portugal blijkt uit de oppervlakte die door deze worden geïrrigeerd. Deze oppervlakte bedroeg in 1979 ongeveer 550,000 ha oftewel 83 procent van de totaal geïrrigeerde oppervlakte in continentaal Portugal. In Trás-os-Montes werden meer dan 1000 FMIS geïdentificeerd die gezamenlijk ongeveer een oppervlakte van 40,000 ha beslaan. Zij zijn geconcentreerd in twee agro-ecologische zones: de 'Bergen' en de 'Hoge Valleien'. Deze zones vormen samen het onderzoeksgebied. Binnen het onderzoeksgebied is er een grote diversiteit in ecologische condities, landbouwsystemen en irrigatiepotentieel.

De landbouw wordt beoefend door kleine boeren. Hun bedrijven zijn verdeeld in vele, verspreide velden. Landbouwsystemen zijn niet gespecialiseerd: een combinatie van landbouw en veeteelt producten dienen voor de voorziening van het huishouden. Tegelijkertijd gebruiken de boeren de gevarieerde fysieke condities om risico's te verminderen en een optimaal gebruik te maken van aanwezige hulpbronnen. Een fundamentele natuurlijke hulpbron in Trás-os-Montes, speciaal in de berggebieden zijn de communale gronden of *baldios*. Zij worden gebruikt voor beweiding, het sprokkelen van brandhout en het verzamelen van materiaal voor de bereiding van ligplaatsen voor vee en organische mest. Boerenhuishoudens zijn met elkaar verbonden door veelvoudige relaties van wederkerige afhankelijkheid. Door deze relaties mobiliseren en ruilen zij hulpbronnen. In de laatste decaden wordt pluriactiviteit steeds belangrijker. Voor velen, is landbouw is een aanvullende activiteit geworden, die voornamelijk produceert voor zelfvoorziening.

Het hele jaar door wordt geïrrigeerd. In de droge zomer worden velden met maïs en aardappelen geïrrigeerd evenals groentetuinen bij huis. Irrigatie in de winter (voor de bescherming tegen vorst en als bemestingspraktijk) en in de lente (voor snelle hergroei) vindt plaats op permanente weiden (*lameiros*), vooral in de berggebieden. Deze *lameiros* zijn een fundamentele peiler van lokale landbouwsystemen. Zij zijn een belangrijke bron van veevoer gedurende praktisch het hele jaar (beweiding) maar speciaal in de winter (hooi). Het beheer, de diversiteit in gebruik en de irrigatie van *lameiros* vereisen een gedetailleerde kennis van lokale veldcondities en vormt een voorbeeld bij uitstek van '*skill-oriented*' tecnologie in Trás-os-Montes. Hetzelfde geldt voor de veldirrigatie praktijken en methoden. Boeren irrigeren bijna alles met oppervlakte methoden. Veldirrigatie in de zomer is zeer efficient, met nauwelijks toedieningsverliezen. De hoge arbeidsinzet is een andere cruciale karakteristiek van irrigatiepraktijken in de zomer. De aard van *lameiro*-irrigatie is lijnrecht tegengesteld aan die van zomerirrigatie. Irrigatie van *lameiros* is arbeidsextensief. De irrigatie kanalen en de veld irrigatiemethode (een variant van de irrigatie door middel van kanalen aangelegd volgens de hoogtelijn) zijn respectievelijk geschikt voor het transporteren en het verdelen van grote hoeveelheden water.

In zijn algemeenheid bestaat er een veelvoud aan water bronnen (oppervlakte- en grondwater) en irrigatiefaciliteiten binnen de dorpsgebieden. Hydrologische karakteristieken omvatten een hoge variatie van waterbeschikbaarheid gedurende de agrarische kalender en een nauwe onderlinge verbinding tussen waterbronnen. De irrigatiesystemen en netwerken bestaan uit verschillende waterbronnen verspreid in het dorpsgebied, reservoirs, kanalen en velden. Ze zijn op verschillende manieren verknoopt en bieden op het eerste gezicht een chaotische indruk. De toegang van boeren tot irrigatiewater onder verschillende eigendommen vormen is vervlochten met deze complexe, onderling gerelateerde irrigatieinfrastructuur. De bijdrage van deze stelsels aan de algehele waterbeschikbaarheid op boerderijniveau is specifiek voor iedere boer.

Het beheer van FMIS wordt gekarakteriseerd door zeer lage transactiekosten. De drijvende kracht achter de dagelijkse werking van de systemen is het eigen belang van de individuele watergebruikers om het water te krijgen waar zij recht op hebben. Dit is vanzelfsprekend en leidt tot een bijna automatische controle en afdwinging van de gebruiksregels. De logica achter het functioneren van het systeem is gegrond op het verdelen van een schaarse hulpbron. Echter binnen deze logica en afhankelijk van de sociaal-economische en fysische context waarin de irrigatie systemen zijn ingebed werken de systemen op heel diverse wijze.

De diversiteit in het functioneren van FMIS is duidelijk gerelateerd aan drie strategische, onderling verbonden sleutel elementen: water beschikbaarheid, water toewijzing en water distributie. Deze elementen en hun onderlinge verbanden zijn flexibel gedurende de agrarische kalender.

De toewijzing van water kan worden gedefinieerd op verschillende gronden. Rechten kunnen worden uitgedrukt in tijdseenheden of in te irrigeren oppervlak of zij zijn niet duidelijk uitgedrukt in vaste criteria. Deze criteria zijn de basis voor de kwalitatieve en/of kwantitatieve toewijzing van water aan rechthebbenden. Een sleutelkwestie die wordt besproken in dit boek is de vertaling van abstracte waterrechten in werkelijke waterhoeveelheden. Gebruiksregels en mechanismen vormen de basis voor een correcte vertaling van toewijzing in distributie. Twee elementen blijken cruciaal: de operatie van reservoirs en compenserende mechanismen. Dit laatste type regels resulteert in het opheffen van variaties in beschikbare irrigatie debieten en het scheppen van gemiddelde gelijke condities voor alle gebruikers om het water te verkrijgen waar zij recht op hebben.

Het resultaat van een veranderde context, gekarakteriseerd door arbeidsschaarste, waarin de landbouwbeoefening en irrigatie zijn ingebed, is een zeer heterogeen beeld van de dynamiek en stagnatie in deze irrigatie systemen. De meerderheid van de systemen functioneert nog steeds en sommige systemen worden nog steeds verbeterd door hun gebruikers. Tegelijkertijd vindt een duidelijke tendens naar involutie plaats. Aan de andere kant is er een onmiskenbare tendens om irrigatiefaciliteiten op individuele basis te creëren, die leiden tot de ondermijning van bestaande irrigatiesystemen.

In Hoofdstuk 3 worden twee studies gepresenteerd van FMIS. In deze casestudies worden de relevante aspecten van het '*skill-oriented*' karakter en het complexe functioneren van FMIS in Trás-os-Montes getoond. Een rudimentaire fysische infrastructuur wordt gecompenseerd door een uitgewerkt systeem van water rechten en een geheel van regels om water toekenning te vertalen in waterverdeling. De casestudies zijn speciaal bedoeld om de lokaal geconstrueerde coherentie te laten zien van de elementen die relatief geïsoleerd van elkaar zijn besproken in hoofdstuk 2.
Water is een essentieel productiemiddel in Trás-os-Montes en als zodanig onderwerp van conflicten tussen mensen. Door specifieke gebruiksregels worden gelijke operationele condities voor de watergebruikers gecreëerd met betrekking tot de variatie van debieten, de timing van irrigatiebeurten enz. Op deze manier wordt illegaal gebruik van water tegengegaan en conflicten tussen gebruikers geminimaliseerd.

De casestudy van het communale irrigatiesysteem van Romainho concentreert zich op het complexe patroon van watertoekenning. Bijna alle watertoekennings-principes en sommige specifieke toekenningsregels zijn aanwezig op meerdere niveaus. Dit huidige patroon is de uitkomst van een lang historisch proces. Het gehele toekenningsschema geeft de indruk van een tendens tot involutie gekarakteriseerd door 'een toenemende vasthoudendheid aan het grondpatroon, de gotische uitwerking van technische en organisatorisch detail, technische haarkloverij en oneindige virtuositeit' (Geertz, 1963). Ofschoon een potentieel tot verandering bestaat is het is de vraag of dit zich zal verwezenlijken. Misschien was een recente verbeterings-interventie een gemiste kans om het systeem te reorganiseren.

De casestudy van het communale irrigatiesysteem van Vila Cova laat zien hoe het functioneren van het irrigatie systeem het resultaat is van een proces van het ontwikkelen van gebruiksregels waarin de verschillende belangen van lokale water gebruikers onderling en met de karakteristieken van de natuurlijke omgeving op één lijn worden gebracht. De studie concentreert zich op de complexe vertaling van water toekenning in water verdeling. Gedetailleerde toekenning van water resulteert niet automatisch in fysische verdeling van water. In deze vertaling moeten vele praktische kwesties worden opgelost. Voorbeelden zijn waterverliezen in de kanalen, de reistijden van water in de kanalen, de opeenvolging van irrigatiebeurten en nachtirrigatie die allemaal ongelijke kansen kunnen scheppen voor watergebruikers om hun waterrechten te effectueren. Gebruiksregels zijn noodzakelijk voor deze vertaling. Deze regels tezamen scheppen een continu veranderend patroon van waterstromen dat op het eerste gezicht chaotisch schijnt, maar bij nadere inspectie duidelijk geordend is.

Het eerste gedeelte van Hoofdstuk 4 beschouwt de diepgaande veranderingen in de sociaal-economische omstandigheden van het platteland in Trás-os-Montes dat normaal gepresenteerd wordt als de meest gemarginaliseerde regio in Portugal. Historisch gezien was de sociale gelaagdheid gebaseerd op zeer ongelijke toegang tot land, scherp. Grote armoede was wijdverbreid. Staatsinterventies vanaf de veertiger jaren tot 1974 onder de de Salazar en Caetano regimes hadden de levensomstandigheden van vele mensen op het platteland slechter gemaakt. Deze verslechterde toestand gecombineerd met de sterke behoefte aan industriële arbeidskrachten in West Europa, leidde tot een massale emigratie van het platteland, sinds het eind van de vijftiger jaren. Zulke emigratie had en heeft nog steeds diepgaande en tegenstrijdige effecten op de lokale samenleving en heeft het sociale en fysische landschap in vele aspecten veranderd..

In het tweede gedeelte van het hoofdstuk wordt de diagnose van deze omstandigheden gemaakt door de overheidsorganen en de ontwikkelingsinterventies gebaseerd op deze diagnose, gepresenteerd. Veel van deze interventies zijn geïnitieerd en uitgevoerd in het verband van het geïntegreerde ontwikkelingsproject van Trás-os-Montes (PDRITM) en het speciale programma voor de ontwikkeling van de Portugese landbouw (PEDAP). Deze programma's hadden tot doel de moderniseringvan de landbouwsector. Traditionele landbouw waarin gewasproductie en veeteelt zijn gecombineerd, moesten worden getransformeerd tot intensieve en competitieve veeteeltbedrijven. Om dit doel te bereiken concentreerde het programma zich op het stimuleren van een ontwikkeling gebaseerd op exogene elementen. Zulke veranderingen werden niet beschouwd als louter aanvullend. Zij impliceren een drastische verandering in de sociaal-economische en technische organisatie van landbouwbeoefening. Om dit proces te versterken kwamen uitgebreide krediet faciliteiten en subsidies beschikbaar. In het exogene ontwikkelingsmodel werden lokaal beschikbare hulpbronnen als overbodig beschouwd, of zelfs een rem op de ontwikkeling, zodat zij vervangen moesten worden. Alléén boerenbedrijven die voldoen aan minimum vereisten, speciaal wat betreft de grootte en de beschikbaarheid van irrigatiewater konden worden gesteund door deze ontwikkelingsprogramma's. Deze toegangscriteria sloten de meerderheid van de boeren uit. Dit is tegengesteld aan het concept van endogene ontwikkeling dat voortbouwt op lokale hulpbronnen, te weten, het bestaande fysische, menselijke en sociale kapitaal.

In de modernisering van de landbouwsector, kent PDRITM een beslissende rol toe aan irrigatie. Dit boek concentreert zich op de rehabilitatie en verbetering van traditionele irrigatiesystemen (MRT). Het uitgangspunt van PDRITM en gerelateerde programma's was dat de verbetering van traditionele irrigatiesystemen basisvoorwaarden zou scheppen voor de modernisering van de landbouw. Dit op haar beurt zou leiden tot een toename van de voederproductie en zo tot een geïntensiveerde veeteelt. Het specifieke doel van de MRT interventie was om de beschikbaarheid van irrigatiewater te vergroten middels het verkleinen van waterverliezen in de kanalen en reservoirs.

In Hoofdstuk 5 wordt de irrigatiewaterbehoefte vergeleken tussen twee modellen: enerzijds de waterbehoefte van exogene landbouwontwikkelingsmodellen, vertegenwoordigd door de boerenbedrijfsstijl van de '*modernisers*', anderzijds de waterbehoefte van endogene landbouwontwikkelingsmodellen, vertegenwoordigd door de boerenbedrijfsstijl van de '*intensifiers*'. Voor dit doel werden de bedrijfseconomische gegevens gebruikt van twee groepen boeren in het berggebied van Barroso, die deze contrasterende ontwikkelings-modellen vertegenwoordigen. Met behulp van een model zijn de relaties tussen de irrigatie-waterbehoefte en bedrijfskenmerken enerzijds en tussen irrigatiewaterbehoefte en de technische-economische bedrijfsresultaten anderzijds geanalyseerd. De belangrijkste conclusies waren:

– de behoefte aan schaars irrigatiewater in de zomer per vee eenheid is veel hoger in het exogene dan in het endogene model.
– de toegevoegde waarde in economische termen per eenheid schaars irrigatiewater is veel hoger bij het endogene model.

Deze resultaten laten zien dat de contrasterende agrarische ontwikkelingsmodellen belangrijke verschillen bevatten met betrekking tot het irrigatiewaterverbruik en mobilisatie. De verklaring hiervoor ligt in het bijzonder in de afhankelijkheid van de 'modernisers' van extra land dat geïrrigeerd kan worden en nieuwe voedergewassen zoals silomais en kunstweide. Daarom is de beschikbaarheid van grote hoeveelheden water in de zomerperiode, wanneer water schaars is, een noodzakelijke voorwaarde voor het welslagen van het exogene ontwikkelingsmodel. De beschikbaarheid van water dient aangepast te worden aan de nieuwe behoeften. Dit vereist hoge investeringen en/of een herverdeling van beschikbare waterbronnen ten koste van andere boeren. Het model van '*intensifiers*' daarentegen, produceert de benodigde hoeveelheid voedergewassen voor de winterperiode met name op de *lameiros*. Deze worden buiten de zomerperiode geïrrigeerd, wanneer regenval en irrigatiewater in overvloed aanwezig zijn. Het endogene agrarische ontwikkelingsmodel gaat uit van de natuurlijke beschikbaarheid van water: de waterbehoefte en irrigatiemethoden zijn daaraan aangepast. In het exogene agrarische ontwikkelingsmodel is echter het evenwicht verstoord tussen de irrigatiewaterbehoefte en de natuurlijke waterbeschikbaarheid. Hierdoor krijgt de modernisering een tendens in de richting van contraproductiviteit voor zover water schaars is. Met andere woorden, in termen van het op waarde schatten van schaarse lokale hulpbronnen is het specifieke endogene model van de '*intensifiers*' duidelijke superieur aan het exogene model van '*modernisers*'.

De eisen gesteld aan irrigatie in het exogene landbouwmodel beperken zich niet tot hogere irrigatiewaterbehoeften. Het arbeidsintensieve karakter van de traditionele irrigatiemethoden botst duidelijk met het tekort aan arbeid dat de meest beperkende factor vormt van het exogene landbouwmodel. Irrigatiepraktijken (het tijdstip van irrigeren, de frequentie van irrigeren etc.) in de bestaande irrigatiesystemen zijn gebonden aan gebruiksregels die sociale akkoorden weerspiegelen over het gemeenschappelijk gebruik van schaarse bronnen welke vaak niet overeenkomen met behoeftes van modernisering die een watervoorziening vereist die gebaseerd is op het maximaliseren van gewasopbrengsten.
Een optimale productie van grote hoeveelheden van moderne voedergewassen zoals silomais en kunstweide vereist het type irrigatiemanagement en technologie dat uitgaat van de gewasbehoeften. Tegelijkertijd moet dit arbeidsbesparing mogelijk maken, bijvoorbeeld in de vorm van nieuwe irrigatiemethoden en/of hogere toedieningsdebieten. Op zijn beurt impliceren deze behoeften toegang tot individuele waterbronnen. Daardoor bestaat er in het exogene model een sterke tendens tot individualisering van toegang tot water.

Theoretisch zou de tendens tot contraproductiviteit in het watergebruik van het exogene model dat leidt tot hogere waterbehoeften kunnen worden gecorrigeerd door een sterke vermindering van waterverliezen en/of een verhoging van de efficiëntie in het watergebruik. In Hoofdstuk 6 wordt dit nader uitgewerkt en bekeken in hoeverre de huidige irrigatieinterventies hier aan bijdragen. De MRT interventie was bedoeld om de beschikbaarheid van irrigatiewater te verhogen door het beperken van waterverliezen. Daarvoor is de toename van het beschikbare irrigatiewater van cruciaal belang. De aannames die ten grondslag liggen aan de MRT interventie worden onderzocht, de verwachte resultaten worden vergeleken met de werkelijke resultaten en de effecten van de MRT interventie worden beschouwd.

Het MRT-programma was gebaseerd op de volgende onderliggende aannames. Ten eerste dat er in de traditionele irrigatiesystemen veel water beschikbaar was. Ten tweede dat de efficiëntie van deze systemen laag is vanwege hun rudimentaire hydraulische infrastructuur. Ten derde werd beweerd dat het irrigatiewater niet productief wordt gebruikt.

Al deze aannames bleken niet juist te zijn. In de eerste plaats is geconcludeerd uit metingen aan de waterbronnen dat de beschikbare hoeveelheid water veel te hoog was ingeschat. In de tweede plaats tonen metingen van verliezen in irrigatiekanalen aan dat het voorkomen van waterverliezen door het bekleden van kanalen in geen geval algemeen of uniform is maar sterk afhangt van de lokale hydrologische omstandigheden, andere natuurlijke factoren maar ook van gebruiksregels. In sommige irrigatiesystemen wordt zelfs meer water gemeten in de stroomrichting! Verder kan men zich afvragen of waterverliezen in kanalen als werkelijke verliezen kunnen worden opgevat. De hydrologische situatie in veel dorpen wordt gekenmerkt door het veelvuldig voorkomen van verspreide waterbronnen die onderling met elkaar in verband staan. Het waterverlies van één bron kan heel goed resulteren in winst voor een andere waterbron. In zulke gevallen heeft het bekleden van kanalen slechts herverdelende effecten. Conceptueel zijn deze effecten vergelijkbaar met de herverdeling van water die voorkomt wanneer bestaande waterbronnen opdrogen, als gevolg van de installatie van nieuwe individuele waterbronnen. *De wenselijkheid van deze effecten kan niet alleen vastgesteld worden met behulp van technische regels alleen.* De gehele lokale context moet in beschouwing worden genomen.

De derde aanname, namelijk dat deze irrigatiesystemen niet productief gebruikt worden is niet gebaseerd op waarnemingen en heeft geen theoretische basis. Maximale gewasproductie als criterium is niet geschikt voor deze systemen omdat in de zomer het irrigatiewater schaars is in relatie tot het beschikbare land. Normaal wordt de productie per eenheid water geoptimaliseerd. Dit blijkt uit het feit dat in de praktijk op grote schaal onderirrigatie wordt toegepast.

Dus, in tegenstelling tot de bewering dat het watergebruik niet efficiënt en onproductief is, wijst deze praktijk op een efficiënt gebruik van schaars water. Bovendien is de irrigatie, gebaseerd op het delen van een schaarse hulpbron, hetgeen vanuit een nauw technisch gezichtspunt als inefficiënt wordt beschouwd maar vanuit het gezichtspunt van gebruikerszelfbeheer het meest optimaal en duurzaam kan zijn. Het verschil zit in de lage transactiekosten en de eenvoudige controleerbaarheid. Flexibiliteit en gebruik van water, in overeenstemming met haar economische waarde, is in deze systemen gebaseerd op een raamwerk van bestaande gebruiksregels en landbouwsystemen.

Bovendien is voor de meest belangrijke irrigatiemethode, namelijk de irrigatie van hooilanden die 2/3 van het geïrrigeerde oppervlak beslaat, efficiënt gebruik niet relevant gezien de overvloed van water in de herfst, winter en voorjaar. Een inefficiënt gebruik is zelfs gunstig omdat dit bijdraagt aan de aanvulling van grondwatervoorraden.

Uitgaande van de impact in het veld, heeft de MRT interventie slechts marginaal bijgedragen aan de productiedoelstellingen van het PDRITM ontwikkelingsprogramma. De traditionele landbouw is niet omgevormd. Voor de meeste boeren genereerde de MRT interventie positieve alhoewel beperkte en heterogene resultaten. De MRT interventie betekende voor hen hoofdzakelijk een goedkope opknapbeurt van hun systemen.

De MRT als een standaard interventiepraktijk gericht op het verminderen van waterverliezen door het bekleden van irrigatiekanalen, is uitgevoerd in een heterogene, diverse omgeving. De effecten kunnen worden opgevat als het resultaat van de interactie van een standaard interventiepakket met de bestaande veelzijdige diversiteit in het veld (fysische en socio-economische context, landbouwsystemen, waterbronnen en waterbeschikbaarheid, water-verdeling en distributie en dynamische aspecten, etc.)

Over het algemeen is de toename in de beschikbaarheid van water als effect van de interventie beperkt. In de praktijk is amper geconstateerd dat het geïrrigeerde areaal groter is geworden. In veel systemen is de cruciale factor de beschikbaarheid van water op het niveau van de waterbronnen en heeft bekleding geen effect op het brondebiet en het regiem hiervan (regelmatigheid en betrouwbaarheid). De MRT interventie creëert niet méér water maar herverdeelt bestaand water. Bovendien is de MRT interventie niet van belang voor *lameiro* (hooilanden)irrigatie omdat er aan water in het algemeen buiten de zomerperiode geen tekort bestaat.
Op productieniveau levert de toename in water nauwelijks de voorziene verhoging op van de productie van met name geïrrigeerde voedergewassen. Voor de ontwikkeling van het exogene landbouwmodel heeft de MRT interventie niet substantieel meer water opgeleverd noch arbeidsbesparende technologieën en de daar nauw mee samenhangende reorganisatie van de ruimte, noch veranderingen in het beheer van de systemen.
In het algemeen hebben boeren de grotere beschikbaarheid van water benut om de irrigatie van traditionele gewassen te verbeteren en om traditionele irrigatiemethoden flexibeler te maken. Veel boeren noemen de afname van de werklast van de irrigatieactiviteiten als het belangrijkste resultaat van de interventie.

Hoofdstuk 7 geeft enkele ideeën en benaderingen om irrigatie interventies te verbeteren en FMIS te herontwerpen. Deze bijdrage kan slechts zeer bescheiden zijn omdat irrigatie geen *panacea* is voor het geheel van complexe problemen waar de landbouwontwikkeling in Tras-os-Montes en andere gemarginaliseerde gebieden mee heeft te kampen. Irrigatie kan alleen een strategisch element vormen (in samenhang met andere) in een integrale benadering voor plattelandsontwikkeling. Als uitgangspunt geldt dat uitgaan en verbeteren van het menselijk kapitaal en natuurlijke hulpbronnen de basis vormt voor een duurzame plattelands-ontwikkeling. Bij dit uitgangspunt wordt de ontwikkeling van irrigatie gebaseerd op het potentieel van de FMIS en de aanpassing van de irrigatiesystemen aan een veranderende context. Dit is uitgewerkt op drie niveaus.

In het eerste deel van dit hoofdstuk wordt de landbouwproblematiek in Tras-os-Montes en met name in Barroso opnieuw onder de loep genomen. Daartoe wordt een vergelijking gemaakt tussen het potentiële effect van de twee contrasterende ontwikkelingsmodellen (de '*modernisers*' vs. de '*intensifiers*') op het gebruik van hulpbronnen en de werkgelegenheid. Deze vergelijking laat zien dat een extrapolatie naar een regionaal niveau (van Barroso) betekent dat het endogene ontwikkelingsmodel-door het verbeterde gebruik van lokale (natuurlijke) hulpbronnen-potentieel meer werkgelegenheid schept dan het exogene ontwikkelingmodel, bij een gelijk arbeidsinkomen. Afgezien van dit potentiële effect op werkgelegenheid en inkomen, is de boerenbedrijfsstijl van de '*intensifiers*' gebaseerd op het gebruik en de reproductie van lokale ecologische omstandigheden en natuurlijke hulpbronnen, die het landschap en de fysische omgeving beschermen en onderhouden. Verder leidt de combinatie van lage externe input en hogere opbrengstprijzen tot een hogere lokale toegevoegde waarde.

Het exogene model pretendeert het inkomen van boeren te verhogen door de landbouwbeoefening en productieomstandigheden te transformeren. Echter, er zijn een aantal argumenten te noemen die

de levensvatbaarheid van exogene landbouwontwikkelings-modellen en hun bijdrage aan de regionale landbouwontwikkeling in Trás-os-Montes ter discussie stellen. Ten eerste is deze vorm van landbouw afhankelijk van externe input- en outputmarkten voor bulkproducten. Ten tweede falen exogene ontwikkelingsmodellen in het voortbouwen op de sterke punten van de traditionele landbouw, zoals ecologisch gezond boeren en het gebruik van lokale hulpbronnen. Ten derde zijn de transformatie kosten van huidige modernisatieprojecten aanzienlijk, zowel intern als over de grenzen van de individuele boerderij. Deze kosten zijn met name hoog in de zogenoemde marginale of minder bevoorrechte gebieden. Voor de 'moderne' boerderij moeten nieuwe omstandighden worden gecreëerd waarin haar ontwikkeling mogelijk wordt gemaakt.
De conclusie wordt getrokken dat er een aanzienlijk potentieel bestaat voor vergroting van inkomen en werkgelegenheid op regionale schaal, gebaseerd op de ontwikkeling van het endogene landbouwmodel van de '*intensifiers*' en dit vormt een cruciale voorwaarde om een verdergaande desertificatie en ontvolking van de plattelandsgebieden in Trás-os-Montes te voorkomen.

Maar de endogene benadering van ontwikkeling heeft gevolgen voor de meest geëigende vorm van irrigatieontwikkeling en de externe hulp die hiervoor nodig is. Deze verschilt van de exogene benadering. Om een evenwichtige planttelandsontwikkeling te bewerkstelligen is het nodig dat de diversiteit van de landbouwbeoefening als uitgangspunt wordt genomen voor een geschikt beleid van rurale en landbouwkundige interventies. Maar een dergelijke herorientatie zal veel obstakels en belemmeringen moeten overwinnen teneinde dit *endogene potentieel* te bewerkstelligen. Alleen door interrelaties te creëren tussen lokale praktijken en hulpbronnen, productieketens, sociale dragers, boerenbedrijfsstijlen en de sociale organisatie, kan een effectief proces van endogene ontwikkeling op gang gebracht worden. Deze zullen op elkaar moeten worden afgestemd.. Ten tweede behoeft schaalvergroting (arbeids objecten/arbeidseenheid) specifieke arbeidsbesparende technologie. Een cruciale ondersteuning voor schaalvergroting en arbeidsproductiviteit zou het ontwerpen en ontwikkelen zijn van een geëigend aanbod van aan lokale omstandigheden aangepaste technologie.

De twee contrasterende landbouwkundige ontwikkelingsmodellen leiden tot verschillende gevolgtrekkingen voor irrigatie interventies. Het inkomen in het endogene model van de '*intensifiers*' hangt slechts voor een klein deel af van het schaarse water in de zomer. De *baldios* (gemeenschappelijke weidegronden) en *lameiros* (hooi en weide) dekken namelijk de basisbehoefte aan voedergewassen. De ontwikkeling van het exogene model is evenwel sterk afhankelijk van grotere hoeveelheden schaars water in de zomer. Omdat dit noodzakelijke water binnen de bestaande irrigatiesystemen nauwelijks aanwezig is, is het nodig om 'nieuw' water te creëren.

Wat betreft het endogene landbouwmodel van de '*intensifiers*', is het mogelijk om de bestaande praktijken verder te ontwikkelen binnen de bestaande irrigatiesystemen. Er zijn twee specifieke ondersteunende acties in de sfeer van irrigatie geïdentificeerd om het potentieel van het endogene landbouwmodel te ontwikkelen. Ten eerste de expansie en intensivering van de geïrrigeerde *lameiros* met het doel de meest beperkende factor weg te nemen met betrekking tot het aantal eenheden vee wat een boerderij kan houden. Ten tweede het revitaliseren van de FMIS door ze aan te passen aan een veranderende context gekenmerkt door schaarste van arbeid.

In de tweede sectie van Hoofdstuk 7 wordt een alternatieve benadering voorgesteld om de lokale irrigatieontwikkeling te versterken. De ontwikkeling van irrigatie treedt op als een gevolg van zowel individuele als collectieve initiatieven van boeren, maar externe actoren kunnen ook een belangrijke rol spelen op dit gebied. Voortbouwend op lokale hulpbronnen, ontwikkelingsperspectieven, kennis van boeren en lokale dynamische factoren worden alternatieve interventie-strategieën geformuleerd die het potentieel in zich herbergen om de huidige institutionele irrigatie interventies te verbeteren. De meest belangrijke zijn:

- De integratie van irrigatie interventies in lokale ontwikkelingsperspectieven.
- Het beschouwen van de besluitvormingsprocedures als een *joint venture* van overheidsinstellingen en lokale watergebruikers. Interventies behoren de lokale dynamiek te ondersteunen en lokale initiatieven te versterken Dit kan door het verschaffen van hulpbronnen die buiten het bereik liggen van de lokale actoren. Externe assistentie is van complementaire aard.
- Het voortbouwen op lokale kennis van boeren over het gebied, de fysieke omstandigheden en de daaraan gerelateerde irrigatiemethoden. Op basis van lokale kennis van waterverliezen zou selectief bekleden efficiënter kunnen zijn. Dat wil zeggen dat de totale verliezen in de kanalen meer af zouden kunnen nemen tegen dezelfde kosten als alleen cruciale delen van de gehele irrigatieinfrastructuur van een dorp bekleed zou worden, in plaats van het integraal bekleden van één kanaal.

In het derde deel van dit hoofdstuk wordt het herontwerpen van FMIS besproken. Het ontwikkelingspotentieel van FMIS en de vertaling hiervan in een coherent technisch en institutioneel ontwerp dat bedoeld is om de systemen aan te passen aan de nieuwe context van de plattelandssamenleving in Trás-os-Montes staat hierbij centraal. De focus is gericht op hoe irrigatie praktijken zouden kunnen worden aangepast aan de schaarste van arbeid.

Een concrete toepassing is het herontwerp van de FMIS in Vila Cova uitgaande van de lokale context waarin irrigatie plaats vindt en de meest belangrijke problemen die genoemd worden door de watergebruikers. Tot in detail wordt besproken welke technische alternatieven er bestaan en welke mogelijkheden er zijn om de FMIS in Vila Cova aan te passen aan de veranderende behoeften van de gebruikers en de veranderende context die gekenmerkt wordt door arbeidsschaarste, voortbouwend op het huidig functioneren en de onderliggende logica die al beschreven is in Hoofdstuk 3. Een correct gedimensioneerd nachtreservoir met eenvoudige operationele eisen is daarbij het meest voor de hand liggend, met het hoogste potentiele effect. Deze oplossing kan in principe vijf onderling samenhangende problemen tegelijkertijd oplossen: de nachtirrigatie komt te vervallen; de arbeidsbehoefte van irrigatieactiviteiten zal afnemen; de waterverdeling kan vereenvoudigd worden; waterverliezen in de kanalen kunnen afnemen; de gebruikers aan het eind van het kanaal (*tailenders*) zullen meer water ontvangen. Uit deze casus kan de conclusie worden getrokken dat er sterke onderlinge samenhang bestaat tussen technische (infrastructurele) en institutionele (gebruiksregels) dimensies van een irrigatiesysteem. Als één element wordt veranderd dan heeft dit gevolgen voor het functioneren van het geheel. De andere elementen die tezamen het irrigatiesysteem vormen ook onderling worden aangepast. Ten tweede kan een passend verbeteringsplan alleen ontworpen worden uitgaande van de lokale situatie en haar mogelijkheden. Ten derde moeten betekenisvolle interventies zich richten op veranderingen in de context waarbinnen landbouw- en irrigatiepraktijken gerealiseerd worden.

Na de presentatie van dit specifieke verbeteringsplan wordt een meer algemeen repertoire van het potentieel voor herontwerpen van FMIS afgeleid die de diversiteit van de systemen dekt. Er moet rekening worden gehouden met de schaarste aan arbeid als één van de fundamentele kenmerken die (op zijn minst gedeeltelijk) opgelost moet worden door interventie. Het zwaartepunt van het reportoire ligt dan ook op interventies die gericht zijn op het besparen van arbeid. De meest belangrijke zijn:

- *De (re)constructie van irrigatiereservoirs*.

De aanleg van een nieuw reservoir moet worden vergezeld van veranderingen in de waterverdeling (gebruiksregels en praktijken) en veranderingen in de watertoewijzingen. De toewijzing van het instromend debiet, het gebruik (ontwerp en regeling) van reservoirs en de verdeling van het uitstromend debiet zijn onderling aan elkaar gerelateerd op specifieke wijze zodat ze wederzijds met elkaar in overeenstemming zijn. Een reservoir met een uitstroomdebiet dat lineair afneemt in de tijd maakt het mogelijk het water te verdelen op basis van tijdsdelen. Dit technisch alternatief heeft het potentieel om interventieperspectieven in FMIS te verbreden. Als zodanig kan dit gebruikt worden als een nieuw interventiegereedschap in verschillende situaties.

- *Het vervangen van kleine reservoirs door grotere*.

De arbeidsbehoefte zou hierdoor aanzienlijk kunnen worden teruggebracht en tevens kan de flexibiliteit in het aanwenden van arbeid vergroot worden indien bestaande reservoirs zouden kunnen worden uitgebreid óf als nieuwe reservoirs met een grotere capaciteit gebouwd zouden kunnen worden. De regels voor waterverdeling en methoden in het watergebruik moeten worden aangepast. Met name de combinatie van reservoirs met een relatief grote capaciteit, tezamen met een lineair afnemend uitstroomdebiet bezit een groot potentieel voor het verbreden van de inhoud van irrigatie interventies. Behalve de potentiële arbeidsbesparing hebben deze grotere reservoirs twee bijkomende voordelen. Ten eerste kan de periode dat deze reservoirs in werking zijn beter afgestemd worden op de behoeften van pluriactieve boeren. Een tweede voordeel is dat door meer geconcentreerde waterstromen, de verliezen in de kanalen kunnen worden teruggedrongen.

Naast de hydrologische kenmerken van de waterbronnen zijn er drie bestaande elementen die cruciaal zijn in het huidige functioneren van FMIS in Trás-os-Montes. Ten eerste bepaalt de *watertoedeling* wie het recht heeft om het water te gebruiken en hoe deze waterrechten verdeeld zijn onder de gebruikers. Dit element biedt de noodzakelijke zekerheid voor de gebruikers dat ze dat deel van het beschikbare water zullen ontvangen waar ze recht op hebben. Een tweede bestaand element zijn de *compensatiemechanismes*. Bij de vertaling van watertoedeling in waterverdeling zijn deze mechanismen fundamenteel om gelijke operationele condities te creëren voor de gebruikers en variaties in het debiet gelijkelijk te verdelen. Een derde bestaand element vormt het gebruik van *reservoirs*. In vergelijking met situaties zonder reservoir maken ze irrigatie efficiënter, zowel in het beperken van waterverliezen (hogere debieten resulteren in relatief kleinere verliezen) en het verminderen van de arbeidsbehoefte in irrigatieactiviteiten.

Het herontwerpen van FMIS zou kunnen plaatsvinden uitgaande van deze drie fundamentele elementen. Reservoirs samen met compensatie-mechanismen vormen een veelbelovend potentieel voor de verbetering en aanpassing van huidige irrigatiesystemen binnen een context van schaarste aan arbeid. Een ruwe schatting van dit arbeidsbesparend potentieel is gemaakt op het niveau van een ‘gemiddelde’ FMIS, op regionaal niveau en op nationale schaal.

Aangetoond wordt dat dit nieuwe type van interventies gebaseerd kan zijn op reeds bestaande elementen in de systemen en op de huidige logica achter het functioneren van deze systemen. Dit onderschrijft de centrale stelling van dit boek, namelijk dat er een aanzienlijk potentieel schuilt in de in FMIS geïncorporeerde '*skill-oriented*' technologieën, die verder ontwikkelt kunnen worden. Dit nieuwe type van interventies handhaaft de fundamentele kenmerken van FMIS, zoals lage transactiekosten en het verdelen van schaars water met behulp van waterrechten. Tegelijkertijd maakt het efficiëntere en arbeidsbesparende irrigatiemethoden mogelijk, die in het bijzonder aangepast zijn aan de huidige context van schaarste aan arbeid.

Echter, potentieel is één ding, of dat potentieel gerealiseerd zou kunnen worden is iets anders. In sommige gevallen is er onmiskenbaar een dominante trend aanwezig in de richting van het creëren van individuele irrigatie faciliteiten, die het uitvoeren van interventies in FMIS vertragen en zelfs ondermijnen. Voor bepaalde groepen boeren, in het bijzonder die toegang hebben tot kapitaal en subsidies, is het investeren in het ontwikkelen van individuele bronnen een gemakkelijker manier dan mee te doen aan veranderingen in FMIS. In andere gevallen zijn de status quo en gevestigde interesses zo sterk dat stagnatie en involutie tendensen voort zullen gaan.

Aan de andere kant zouden externe actoren (overheidsinstellingen, ingenieurs, etc.) de verwerkelijking van dit potentieel kunnen ondersteunen door mee te werken, te faciliteren en hulpbronnen te verschaffen die momenteel niet beschikbaar zijn. Maar deze ondersteuning moet uitgaan van de situatie zoals die nu is en niet van een aangenomen of 'virtuele' realiteit.

Curruculum

Adriaan Laurentius Josephus van den Dries was born on 26 April 1950 in the Noordoostpolder, the Netherlands. In 1976, he graduated in Tropical Land and Water use at the Wageningen Agricultural University. He gained experience in different types of work in diverse socio-economic, institutional and physical environments. In Mozambique (during 10 years) he worked at various places as irrigation engineer and project manager in irrigation development. In Nicaragua (during 3 years) he was engaged as an adviser in the land reform sector, particularly concerning the evaluation of existing irrigation schemes and applied irrigation technology, the formulation of new proposals and training of technicians. In the framework of an EU-funded research project concerning the identification and strengthening of the development potential of marginal areas, he did research on the role of irrigation in contrasting farming systems and the functioning as well as the possibilities for improvement of farmer-managed irrigation systems in Northern Portugal (during 3 years). From 1996 till 1999 he was working in Angola as manager of water supply rehabilitation projects and as advisor of an autonomous water supply organisation, based on O&M cost recovery, in Kaala town, Huambo province. He has participated during the years in various preparation and evaluation missions of irrigation projects in the Philippines, Ecuador and Mozambique. He lectured intensive training courses in irrigation water management in Pakistan and Mozambique. From February 2000 until October 2001 he prepared and lectured courses at the Irrigation and Water Engineering group of the Wageningen University. He works now as consultant on water and land development.

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