METRIC MATTERS

The performance and organisation of volumetric water control in large-scale irrigation in the North Coast of Peru

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The performance and organisation of volumetric water control in large-scale irrigation in the North Coast of Peru

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Propositions

1. Volumetric water control can only be understood if its three dimensions are taken into account: volumetric water allocation, volumetric water delivery and volumetric water charging.
   (this thesis)

2. Corruption and other 'perverse incentives' can increase the water use efficiency and water delivery performance in irrigation systems.
   (this thesis)

3. Volumetric water delivery achieves high performance in at least one large-scale irrigation system in Peru - despite the use of difficult to operate undershot gates, open canals and requests for water turns from many water users - through the skills of the operators and the accountability of the boards of the water users' associations towards the water users. This accountability is a power relation between the users and their representatives in the boards. The power balance is based on mutual dependency that is created because the board members depend on the support of the water users to maintain their lucrative positions and the water users depend on the board members to maintain and operate the irrigation system is such a way that water can be delivered to them.
   (this thesis)

4. Irrigation Management Transfer (IMT) is like raising a child: step by step you give more responsibility and provide less support to the child, this happens under the conditions set by the parents, and might be liked or not by the child.
   (pers. com. David Groenfeldt, January 2001)

5. There is nothing new to the export of Dutch civil engineering and the Dutch Polder Model. The Dutch Pope Adrian VI in 1522 established peace between the cities of Bologna and Ferrara by ordering Ferrara to close the river spillway called 'Po of Venice' to protect Bologna from overflowing of the Reno river caused by sedimentation in the original course of the Po of Ferrara.
   (Enzo Levi, "The Science of Water: the Foundation of Modern Hydraulics", 1995, p.105-106)

6. El regar con agua de rio es muy trabajoso, necesitándose para esto de máquinas ó instrumentos de norias ó ruedas que deben ser movidas en giro por camellos, asnos ó mulos; cuyas máquinas en la mayor parte estan expuestas á frequentes quiebras. No es pues conveniente usar de este modo de riego, sino quando á ello obligue la necesidad; esto es, quando no pueda adquirise de otra suerte lo necesario para la vida; y en este caso debe uno cuidar de ello por sí mismo; de otro modo le seria el coste crecido y poca la utilidad. Algunas veces se ha hecho la cuenta del gasto que causan los animales [y las máquinas], y se ha hallado que ó se acerca mucho, ó excede á la utilidad de todo el producto.
   (Abu Zacaria, "Libro de Agricultura", original from the 12th century, Spanish translation from Arabic text in reprint from 1802, Tomo I, p.6)

7. Fraud in tendering procedures for big construction works is a good example of 'collective action', indicating that not all collective action should be regarded as beneficial for society.

8. For the thick description of the life of one bureaucrat in a small organisation the Dutch author Voskuil needed 6000 pages (*Het Bureau*, 1996 (vol.1) to 2000 (vol.7)). This implies that the description of the strategic conduct of 200 officials and 130.000 farmers in the 206 pages of this thesis can only be regarded as a very thin description.

9. In some cases rubbish can provide valuable scientific information, in many cases scientific information soon becomes rubbish.

10. A 'work-to-rule' strike shows that in daily practices work is more led by informal rules than by official rules.

11. Farmers engineer better than engineers farm.

12. Meetings would be much more efficient if all participants would adhere to the set agenda. However, the personal agendas of the participants push them to put forward their own issues. Therefore, the social function of meetings should be taken seriously and thus agendas should allow for more flexibility. This also applies to water scheduling.

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Glossary of Spanish words and acronyms

AACH	*Autoridad Autonoma de la Cuenca Hidrografica*, Autonomous Watershed Authority. Local office of the Ministry of Agriculture, which was established in some watersheds in Peru to regulate multi-sectoral water use
aforador	Person who measures water flows in canals and rivers
ATDR	*Administración Técnica del Distrito de Riego*, Local Irrigation Office of the Ministry of Agriculture. This office allocates water and supervises the water users' organisations in an Irrigation District
baja	Unexpected negative flow change
bocatoma	Intake of a canal from a river
cacique	Indigenous leader
campo	Small cluster of fields in Jequetepeque
caporal	farmer appointed informally to supervise canal cleaning
CEPRI Tierras	*Comité Especial de Privatizaciones*, Special governmental commission de privatise land
Comisión de Regantes (CR)	Water users' organisation at the level of secondary canals in large-scale systems (in small-scale systems at the level of the irrigation system)
Comité de Canal (CC)	Water users' organisation at the level of tertiary blocks
Comité de Coordinación	Commission comprised of the ATDR, *Junta de Usuarios* and other stakeholders where the cropping plan (PCR) and adaptations are discussed for an Irrigation District
coordinador técnico	Head engineer working with the *Comisión de Regantes*
cuota	ISF that the *Comisiones de Regantes* establish apart from the *Tarifa de Agua*
DEJEZA	*Dirección Ejecutiva del Proyecto Especial Jequetepeque-Zaña,* Special Project Bureau that forms part of the Ministry of the Presidency. It was created to execute the Jequetepeque-Zaña project financed by the German KfW.
DEPOLTI	*Dirección Ejecutiva del Proyecto Especial Olmos-Tinajones,* Special Project Bureau that forms part of the Ministry of the Presidency. It was created to execute the Olmos-Tinajones project financed by the German KfW
DPR	Delivery Performance Ratio: indicator for the performance of actual water delivery compared with the planned distribution
ECASA	*Empresa Comercial de Arroz S.A.*, Comercial Rice Enterprise, the State rice purchasing entity in socialist Peru (1969-1986)
EPSEL	*Entidad Prestadora de Servicios de Saneamiento de Lambayeque*, municipal drinking water company in Chiclayo
estatutos	Statutes of the *Comisiones de Regantes* regulating responsabilities and sanctions of the board and water users in the *Comisión*
ETc	Crop evopotranspiration
ETECOM S.A.	*Empresa Técnica de Conservación, Operación y Mantenimiento*, Company for Conservation, Operation and Maintenance: private company of the *Junta de Usuarios* in Chancay-Lambayeque
gerente técnico	chief engineer (of the *Junta de Usuarios*, ETECOM, or AACH)
hacienda	Large landholding owned by a *hacendado.*
IMT	Irrigation Management Turnover
ISF	Irrigation Service Fee: the fee the water users have to pay for the delivery of water to their plots

jefe de operaciones	Head engineer working with the *Comisión de Regantes*
jefe de sector	Head engineer working with the *Comisión de Regantes*
Junta de Usuarios (JU)	Water users' organisation at the level of the main system of large-scale irrigation systems in Peru (or sub-watersheds in the mountain areas), it is formed by delegates from the *Comisiones de Regantes*
KfW	*Krediet für Wiederaufbau,* German governmental development bank that finances large infrastructure projects in low-income countries
licencia	Permanent water right
módulo	Maximum volume of water to be requested per hectare per irrigation season depending on crop
OPEMA	*Operacion y Mantenimiento*, private company of the *Junta de Usuarios* in Jequetepeque
padron de usuarios	List of right holders to irrigation water
PCR	*Plan de Cultivo y Riego*, has two related meanings (1) the overall cropping and irrigation plan for the irrigation system for one year, (2) the document each individual titleholder receives from the ATDR at the start of each irrigation season indicating the crop allowed to be grown and the volume of water allowed to be requested for that crop
permiso	Excess water right
PETT	*Programa de Titulación de Tierras:* Program of the Ministry of Agriculture for the regisration of individual land titles
presidente	President of *Comité de Canal, Comisión de Regantes or Junta de Usuarios*
PSI	*Programa de Subsectores de Irrigación*, project for rehabilitation and training in the coastal irrigation systems if Peru, financed by the World Bank
rango	Rule that establishes the proportion of the land of each individual plot holder entitled to water scheduling in water scarce periods in Chancay-Lambayeque. The bigger the landholding the bigger the percentage of reduction of the entitled area
repartidor	Person that schedules and distributes water in the tertiary block. He is appointed and paid by the water users in the tertiary block
riego	Water flow of 160 l/s during one hour (thus 576 m^3) delivered at field level
riego volante	illegal water turn
RWS	Relative Water Supply, indicator of the adequacy of the water application according to the crop water requirements
SARA	*Sistema de Administración y Registro de Agua*, Automated system for registration of water allocation and delivery
sectorista	Person that schedules and distributes water in a part of the secondary canal. He is hired by the *Comision de Regantes*
SENAMHI	*Servicio Nacional de Meteorologia y Hidrologia*, Peruvian meteorological institute
Subsector	Part of the Irrigation District that is managed by a *Comisión de Regantes*
tarifa de agua	Water tariff that is paid by the water users to the *Junta de Usuarios* for the delivery of irrigation water
toma libre	Right to take was much water as the canal can take
tomero	*Person who operates the gates along a main or secondary canal. He is hired by the private company of the Junta de Usuarios or the Comisiones de Regantes*
VWC	Volumetric Water Control: the allocation, scheduling, delivery and payment of irrigation water by volume
WUA	Water Users' Association

Preface

Unravelling the seemingly endless knot of hydraulic impossibilities, organisational discontinuities, economic paradoxes, untold histories, and not practiced rules, proved to be a puzzle that always yielded more parts out-of-place than resolved parts.

The fieldwork in Peru was not only puzzling, it was also very joyful. Both in the *oficinas* as in the countryside. Sitting on a bund of a rice field chatting with a farmer would reveal quite different perspectives in comparison with interviews with the *gerente técnico* of the *Junta de Usuarios*. The richness of these contrasting worlds was nice to experience and helpful in the research.

Many people helped with the research. While in Peru, the NGO IMAR Costa Norte provided an office and much information and contacts. I am grateful to its director Luis Chinchay for facilitating the field research. Other people who worked with IMAR and contributed with their great knowledge on the irrigation system and its managers are: José Muro, Arturo Solorzano, Carmen Rosa Hidrogo, Javier Odar, Piet Sijbrandij, Antoinette Kome and Ysbrand Galama.

During the six months flow measurement program and the farmers surveys five students from the local university assisted. Karina Pozo, Edilberto Acosta, Christian Reque, Carlos Cruzado and Aldo Mendoza contributed, all in their own way, to the fieldwork. Pieter Waalewijn helped in doing some complementary measurements and observations. Special thanks are due to Alex Guimac, who helped with all sorts of information, and provided explanation of many happenings, both locally and nationally, both related to irrigated agriculture and related to any other aspect of Peruvian life.

Further I want to thank the farmers, farmer-representatives, staff of the *Comisiones* and *Juntas* and government officials for the time dedicated to my 'endless' interrogations. Without their willingness to answer my questions and explain complicated matters to me the thesis would never have gained the same 'depth'.

Back in Wageningen several people helped with the difficult process of writing the story down. In the first place the promotors of the thesis: Linden Vincent and Franz von Benda-Beckmann offered much needed support, valuable critique and guidance. They dedicated much work in directing the thesis to become more consistent, logic and informative.

At the Irrigation and Water Engineering Group in Wageningen several people were helpful in reading and commenting on earlier versions of parts of the thesis: Rutgerd Boelens, Alex Bolding, Edwin Rap, Jeroen Warner, Flip Wester and Margreet Zwarteveen. Wim Kloezen and Peter Mollinga contributed in earlier phases of the research. I want to thank them all for the useful discussions and literature suggestions.

Finally I want to thank Saskia van Orsel for supporting me during the period of field research and thesis writing period.

Wageningen, April 2002

1. Introduction

1.1 Research theme: volumetric water control

Water of sufficient quality is increasingly becoming a scarce resource in many parts of the world. Irrigation is, and will be, the most important user of the world's freshwater resources. It is estimated that in 1995 of a total of 2,100 cubic kilometres freshwater consumed worldwide, irrigation used 1,750 km^3, or 83% (Shiklomanov 1999). Performance of large-scale irrigation is regarded as unnecessarily poor in most irrigation systems in the world (Botrall 1981, Bromley 1982, Repetto 1986, Postel 1992, FAO 1996). Or as Cosgrove and Rijsberman (2000:ix) stated in a document presented during the World Water Forum 2000: *"There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people-and the environment-suffer badly".*

Irrigation in coastal Peru takes place in an arid environment, and is subject of much management debate about its improvement. This thesis takes up questions of whether the large-scale irrigation systems in this area are really badly managed, or whether technologies and institutions evolved have created more optimal management than critics assume.

Poor performance of large-scale irrigation has different facets. Four related aspects can be defined: allocative, field-application, financial and hydraulic performance. Allocative performance is concerned with the economic benefit generated with the available water (Allan 1999). Pro-market experts assert that with free markets for water and water rights, water will automatically flow to the user who will use the water in most economically efficient ways (Rosegrant and Binswanger 1994, Winpenny 1994, Tsur and Dinar 1997). However, there are very few examples of water markets that are actually functioning (see Bauer 1997 and 1998 for the problems with water markets in Chile). Field application efficiency is the percentage of the applied water actually used by the crop. In many cases more water is applied than needed by the crop, for example to substitute for labour (Wolf *et al.* 1996). The financial performance of large-scale irrigation is regarded as poor. Many subsidies come in and the fee recovery rate is low (Repetto 1986, Small and Carruthers 1991). The low fee-recovery affects negatively the maintenance, which in turn inhibits a proper water distribution (Sagardoy 1996). Also the hydraulic performance of many large-scale irrigation systems is considered poor. The water is not delivered as planned and water supply to the tail-end of the systems is erratic, if water reaches the tail at all.

Depending on the discipline, each irrigation expert offers its own solution to the above mentioned problems. One idea that addresses many of the above problems is 'volumetric water control' (VWC). In a system with VWC the users request water and are charged for the exact volume of water consumed at field level. Water flow is measured at field or tertiary block level. The farmers, thus, have an incentive to apply not more than just-enough water. Or in the words of the FAO (1996:34): "*Overall, the best chance for improving the efficiency of water delivery is embodied in a system that conveys water in closed conduits and provides measured amounts of water on demand, at a rate calibrated to meet continuous crop needs while preventing waste, salinity and water-table rise.*" Van Hofwegen states (1996:333): "*Cost recovery based on volumetric payment can be a useful means to introduce effective irrigation scheduling. This helps to develop effective accountability mechanisms, enhance system performance and improves water use efficiency.*" Grimble (1999:80) underpins the economic rationality of volumetric water control: "*If economic pricing is to be an effective instrument for efficient water utilisation the amount paid by the user needs to be related to actual consumption. (...) Any system for charging loses its point as an aid to efficiency where the user himself is not able to control supply and determine how much water to use.*"

Volumetric water control is often presented as a 'modern' solution that will increase technical and economic efficiencies. However, the idea is quite old, and was already experimented with in 1903 in British India (Bolding *et al.* 1995). Also in Peru the concept was already introduced during an irrigation congress in 1928.

Volumetric water control is not without difficulties. In large-scale systems it is very difficult to measure and register all water flows to many smallholders. In addition, no appropriate procedures might be in place to establish a proper price to be paid per unit of water. A too low price will undermine the effect of the pricing on the efficiency and the cost-recovery. A high water price might cause social differentiation. Finally, the distribution of exact volumes is likely to be challenging in large-scale systems with open canals and manually operated undershot sliding gates, especially when the supply is irregular.

This study presents the cases of two large-scale irrigation systems on the arid North Coast of Peru. In one of the systems volumetric water control was practised ... and with success! In Chancay-Lambayeque the users pay per volume of water requested at field level. This water is distributed in open canals and regulated by manually operated undershot gates. There are few flow measurement structures. The river supply is very irregular. In this 'nightmare'-system the water delivery performance was very good. In the other system, Jequetepeque, the water users paid an area-proportional fee, differentiated for the crop grown. The Water Users' Associations (WUA) - *Junta de Usuarios* and *Comisiones de Regantes* - that have managed the systems since turnover begin 1990s, have been able to establish and recollect fees that cover the operation and most part of the maintenance costs.

How can this be explained? Not only technical and economic factors should be taken into consideration to explain the unexpected success of the volumetric water control in Peru. Also social, institutional and legal factors are important. Large-scale irrigation has a long history in the region. The systems are more than a thousand years old, and although there have been major changes in the governance of the systems, important experiences gained in dealing with water, land, crops and organisation have been institutionalised over time and are still in use. The present social-legal institutions enable a management of the systems in a certain way. The social power balance between water users, the boards of the Water Users' Associations (WUAs) and the different governmental organisations influences the use of natural and human resources. Important power relations include rights to decision making in certain domains and accountability of the board of the WUAs towards the water users. The irrigation infrastructure and operators are scrutinised within the institutional setting to understand the water delivery performance of the irrigation systems.

1.2 Objectives of the research

Studying volumetric water control needs understanding of volumetric water allocation, delivery and charging, and the relations between these dimensions. Many ideas exist both in favour and against volumetric water allocation, charging and delivery. However, not much is known about the different practices that can lie within volumetric control and the institutions it needs, and its effect on operational performance and productivity of water. A lot of arguments in the debates on volumetric water control stem from disciplinary assumptions, for example: 'pressurised pipes will solve the problems of water distribution', 'marginal cost pricing will solve the inefficient water use', and 'getting the process of organisation right' will solve the problems in the irrigation sector'.

The main objective of the research is to present and analyse two case studies on volumetric water control in Peru. The case studies highlight the influences of physical and social factors on the performance and organisation. The complex relations are described so as to gain insight into the realities of volumetric water allocation, scheduling, delivery and charging. As Moore (1989) states, there are very few cases documented of actual practices of volumetric water pricing in large-scale gravity irrigation systems with many smallholders in low-income countries.

The relevance of the research on volumetric water control in the two irrigation systems in Peru can be seen from various perspectives. In general terms the research is relevant because in many parts of the world water of good quality is getting scarcer. There is little profound, integrated, and interdisciplinary knowledge, and few theories are available to understand the performance and practice of operation of large-scale irrigation systems. At the national level in Peru the research is relevant because improvement of water use efficiency is much debated in light of a proposed new water law (Del Castillo 1994, Oré 1998). In the new law, water rights would be tradable to increase the water use efficiency. This research could contribute by showing a detailed case study on water use and showing the diversity of factors influencing performance and actual water use efficiencies. Locally, in the irrigation systems themselves, other issues are debated. The price of water and the related level of maintenance needed are examples of local concern and debate. This study is relevant here, because it gives detailed information and analyses on water pricing, and its relation with operation and maintenance.

The research aims to develop an interdisciplinary framework for analysing management and water use in large-scale irrigation. It draws on technical and management concepts used in irrigation studies and concepts from the social and legal sciences. It is however not the objective to develop further sociological or legal theories.

1.3 Irrigation in Peru

Peru is a country with great inequity in the distribution of resources. This applies to the regional distribution of the rainfall: an extremely arid Coast (less than 50 mm per year), dry and humid parts in the mountains and a humid rainforest (3000 mm per year). It also applies to the distribution of wealth. The 20% of richest people possess more than 50% of financial resources. Eight million of the total of 24 million inhabitants of Peru live in the capital Lima, most of them in the poor shantytowns. Agriculture provides work for almost one third of the workforce, but only generates 6% of the GNP (Thobani 1995).

Both in the Andean Mountains and the extreme dry coastal plain of Peru, irrigation is of utmost importance for the inhabitants of these areas. Since settlement began in both regions, some 12,000 years ago, enormous efforts have been put in construction of irrigation systems, and highly sophisticated skills in construction and operation were developed by the local irrigation communities (Kosok 1965, Ortloff 1988, Sandweiss 1995).

Peru can be divided into three zones with completely different topography and climate: the Coast (*Costa*), the Andean Highlands (*Sierra*) and the Amazon jungle area (*Selva*). In table 1.1 the total extension of these zones is indicated, as well as the areas cultivated and areas irrigated.

Table 1.1: Total, cultivated and irrigated areas in Peru (Sources: Carrasco *et al.* 1993 and Thobani 1995)

	Coast (*Costa*)	**Mountains** (*Sierra*)	**Jungle** (*Selva*)	**Total Peru**
Total area	14 million km^2	39 million km^2	76 million km^2	129 million km^2
Cultivated area	850,000 ha	1,500,000 ha	400,000 ha*	2,750,000 ha
Irrigated area	839,000 ha	811,000 ha	79,000 ha	1,729,000 ha

* About 200,000 ha illegal coca growing is not included.

The cultivated areas in the Andes are partly rainfed and partly irrigated. Irrigation might be only supplementary and be used only during a short period or for specific crops. Most irrigation systems are small-scale and maintained and operated by the users (Dourojeanni and Molina 1983, Guillet and Mitchell 1994, Boelens 1998). The history of these Andean systems differs. Some were constructed during the Inca period (Sherbondy 1994). Some were built later by the local communities. However, many were constructed by *haciendas*. After the land reform of 1969, the government and local communities started to fight for control over these systems (Lynch 1988, Gelles 1994, Guillet 1994).

In the Amazon jungle the main problem is the uncontrolled clear cutting of rainforest for timber. Near roads and settlements, first clear cutting, followed by agriculture, causes severe damage to the ecosystem. Even if the rainforest has a humid climate, once the forest has gone the soil becomes nutrient poor and dries very rapidly. Hardly any irrigation projects have been constructed nor are planned in the *Selva*. However, because of the drought caused by clear-cutting and the pressure on land in other areas of Peru, irrigation might be considered as a means to increase production in the Amazon basin (Zavaleta 1987).

The coastal plain is only 10% of the total surface of Peru, and contains only 30% of the cultivated area, but commercial agriculture is mainly concentrated here. Sixty percent of the GNP in agriculture comes from the Coast (Thobani 1995). The Coast is extremely dry and agriculture depends completely on irrigation. Only the El Niño rains make the desert bloom about once every fifteen years. Water comes from 53 rivers, which flow from the Andean Mountains towards the Pacific Ocean. The rivers have been used since ancient times for irrigation (Kosok 1965, Ortloff 1988). One of the problems for the coast irrigation is that the river discharges are very fluctuating and unpredictable. The peak flow of the rivers coincides with the hottest summer month January-March, which makes the growing of rice possible. In the period of July to September the rivers can completely dry up leaving no inflow into the irrigation system. Besides rice, sugarcane, maize and beans are the main crops.

The commercial farming of cotton, rice and sugarcane was concentrated on large *haciendas* until the 1969 Land Reform (Ramirez 1974, Keith 1976 and Rischar 1991). The Agrarian Reform changed the economic structure of the agriculture: first in co-operatives and after 1983 in individual landholdings, the new owners continued the high input cultivation, but in most cases lacked organisation and credit to improve their livelihoods (Melmed and Carter 1991). From 1989 onwards the large-scale irrigation systems of the Coast were transferred from the Ministry of Agriculture to WUAs (Oré 1998). Subsequently, the main problem now became the cost recovery for operation and maintenance by the WUAs. Another problem facing coastal irrigation is salinity (Alva *et al.* 1976).

Figure 1.1 shows the main irrigation systems in the North Coast of Peru. From North to South one can see the Chica-Piura system, the small Rio Leche system, the Chancay-Lambayeque system, the small Zaña system, the Jequetepeque system and the Chavimochic system.

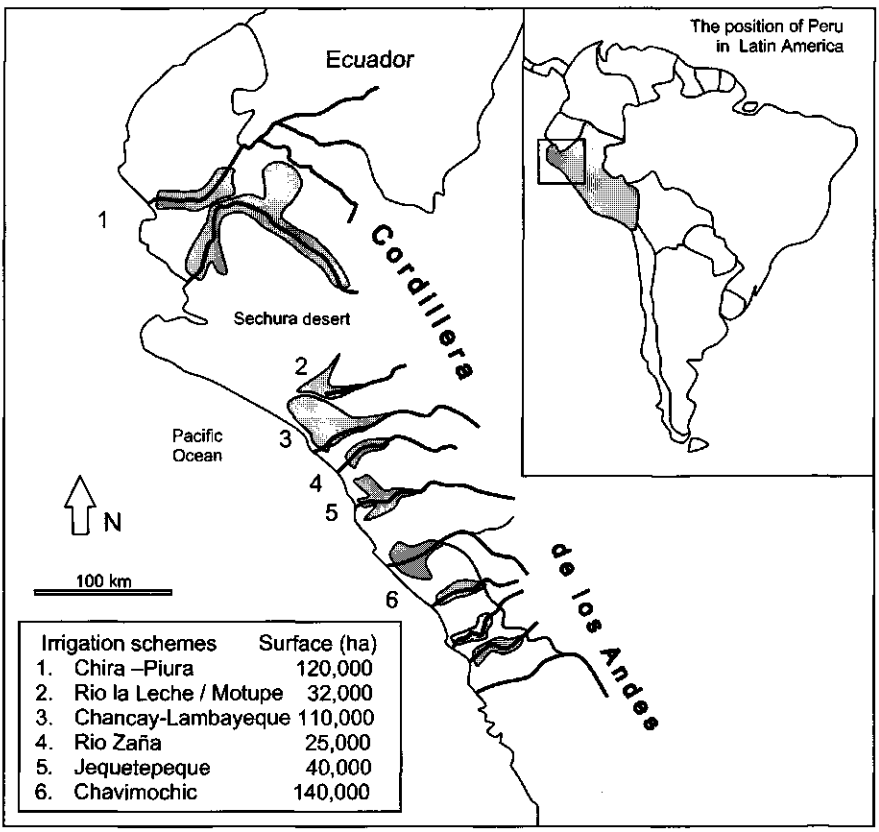

Figure 1.1: Map of the North Coast of Peru indicating the location of the most important irrigation systems

As can be seen from the figure, the irrigated areas are situated near the coastline, so that water lost by percolation cannot be used further downstream in the river basin. All these irrigation systems have a long history. Irrigation has been practised for more than a thousand years. During the last century big infrastructural projects have been executed to increase the command areas of the existing systems (Cleaves and Scurrah 1980, Urban 1990) spending for all coastal systems a total of about US$ 3.4 billion to extend or rehabilitate about 300,000 ha (Thobani 1995).

The Chira-Piura, Chancay-Lambayeque, Jequetepeque and Chavimochic systems have all undergone modernisation. The most important changes in all projects were: building of a main storage reservoir, building of main intake works, lining of (existing) main canals and sometimes the diversion of water from other watersheds. The reservoirs have mostly a limited capacity, which is not sufficient for one growing season, and do not fill every year. The Rio Leche-Motupe and Zaña irrigation systems have undergone very little change over the past hundreds of years. The main intake weir in the river is still made of stones and logs (Eling 1987) and no reservoirs have been built.

The Chavimochic system has been expanded the most recently (1990-2000). It is the only system where large plots have been sold to companies and where drip irrigation is practised. The other systems have mainly smallholders and middle sized landowners (all mainly producing for the market) and use open, mostly unlined, canals to distribute the water. Field application is mostly by basin irrigation. Water is not pumped and hardly any ground water is used. The division structures are adjustable undershot sliding gates. Some specialists (for example: Toledo 1999, Vásquez and Turkowsky 2001) regard the water user in coastal irrigation in Peru as highly inefficient.

1.4 The problem definition for the two case studies

The field study concentrated on two irrigation systems in the North Coast: Chancay-Lambayeque and Jequetepeque. Chancay-Lambayeque (110,000 ha) is the only one of the four large-scale irrigation schemes where volumetric charging is practised. Water users request a water turn and pay US$ 2 per hour with a water flow of 160 l/s. This system was compared with the Jequetepeque system (40,000 ha) where water users pay a fixed, area-based, water charge according to the crop cultivated. This system is also used in most other irrigation systems on the Coast of Peru. Jequetepeque was selected because it is situated closest to the Chancay-Lambayeque system compared with the other large scale irrigation systems that have a reservoir, only separated by desert land of 50 km. The other large-scale systems: Chira-Piura (120,000 ha) and Chavimochic (140,000 ha) are situated at larger distances (200 and 150 km resp.). It must also be noticed that Chancay-Lambayeque and Jequetepeque are considered as the two most successfully managed irrigation systems in Peru. These systems are presented by the government as examples to other systems in the country.

The research focused on the difference between Chancay-Lambayeque and Jequetepeque in water use and organisation. One of the important factors is the volumetric charging practised in Chancay-Lambayeque. However, other factors influenced water use as well. The volumetric allocation, which was established by the local irrigation office of the Ministry of Agriculture (ATDR), on the basis of historic water rights and political decisions, was also very important. It is presumed that studying the actual daily practices of water allocation, scheduling, delivery and charging is necessary to understand the effect of volumetric pricing of water.

Why is the discussion on volumetric water control relevant for the North Coast of Peru? Five reasons:

- First, irrigation forms an important part of the livelihoods and social life of the water users in the irrigation systems. Issues of equity, and productivity related to water distribution are important matters, widely discussed among the water users.
- Second, the coastal irrigation systems have on average a low productivity of water and there is a potential for the use of possibly saved water on the arid plains bordering the existing irrigation schemes.
- Third, the actual allocation of water has two problems: the supply is irregular and insecure because of the fluctuating and unpredictable discharges of the rivers and the allocation in unequal: some users can take a lot of water for irrigating sugarcane and other water users can apply only little water for their maize and beans. Over-irrigation in combination with poor drainage also leads to water logging and thereby salinisation (Alva *et al.* 1976, IMAR 1997b).
- Fourth, water pricing is relevant for the WUAs because the users themselves have to finance the O&M of their systems. The water users' associations have gained important political significance after the Irrigation Management Turnover (IMT) from 1992 onwards. In Chancay-Lambayeque they charge users for the consumed volume at field level. In other systems on the Coast the Irrigation Service Fee (ISF) is a fixed fee per hectare according to the type of crop allowed to be grown.
- Finally, the operation of the sliding gates in combination with the on-request scheduling and irregular river flows is supposed to raise a number of difficulties for water control in the systems. This makes the cases interesting in a comparison of water delivery performance with other cases presented in literature.

1.5 Analytical framework

The analytical framework is split into two main parts. In the first part the three dimensions of volumetric water control will be worked out. In the second part the analytical tools used in the research will be introduced. These analytical tools concentrate around three themes: irrigation as a sociotechnical phenomenon, irrigation technology, and power relations in and among the water users' associations and governmental agencies.

1.5.1 Analysing volumetric water control

Volumetric water control (VWC) is a system of water allocation, delivery and charging where exact volumes are assigned on request to individual plot holders or groups or irrigators. The water users pay per unit of consumed water. The system of volumetric water control implies a precise water distribution and measurement of the flows. It also implies a registration of the water used by each water user. It is important to stress that the three dimensions of volumetric water control: allocation, delivery and charging are all essential for the notion of volumetric water control: volumetric water allocation implies volumetric water delivery, and without volumetric payment the on-request allocation in water scarce situations will not work.

The main reason to promote volumetric water control is to increase the efficient use of water at field level by providing an incentive for the water user to save water. The idea is that water users will request the volumes of water that the crops require and not more than that. The water provision for the crops is thus optimised, while wastage of water is prevented. This requires a charge per unit of water sufficiently high to prevent the farmer from using water as a substitute for labour or other inputs. Charging per volume might also increase the fee recovery, although fee recovery could also be improved with area-based fees.

The idea of VWC has a long history. Volumetric pricing was introduced -albeit without much success- in the large-scale irrigation systems in British Bombay Presidency in 1903 (Bolding *et al.* 1995) and in Punjab in 1917 (Erry 1936). The discussion on volumetric water control in those times was recorded in the proceedings of irrigation congresses in Pakistan in 1936 (Erry *ibid.*) as well as in Peru in 1928 (Anon. 1929). Both in Peru as in Asia the idea of volumetric water control was influenced by the irrigation systems in Spain, France and especially the United States. The discussions in Pakistan make clear that many of the present day arguments (volumetric charging is not fair, measurement at field level is not possible, unsteady flow makes flexible deliveries difficult, etc.) are of the same nature as the arguments raised then.

Volumetric water allocation and scheduling

Water allocation[1] is the assignment of a certain volume or flow of water to a certain title-holder or part of an irrigation system (to be delivered during a certain period). Scheduling is the determination of when, how long and where a certain flow or volume shall be delivered based on the allocation and legislation and local rules concerning delivery. There are two basic modes of water allocation: share based allocation (or supply-based allocation) and volumetric allocation (or demand-based allocation) (see for example Goussard 1996). In Appendix I examples are given of share-based and volume-based irrigation systems.

In a share-based allocation system an individual water user (or group of water users) receives a certain amount of water on the basis of a share-based water right or imposed irrigation schedule. An example of share-based water allocation is the allocation of water in the wet season in Farmer Managed Irrigation Systems in the Hills of Nepal. According to land holding or investment in the construction, a share-based water right is allocated to a farmer. This farmer can use for example one percent of the total flow diverted from the river on her or his land (see Martin 1986). An example of an imposed share-based water allocation is the protective irrigation in the Tungabhadra system in South India (Mollinga 1998a). In both systems the water users themselves are supposed to adapt their cropping practices to the imposed supply. A share-based system, thus, also supplies a certain volume in a certain time period to a certain plot (like a volumetric water control system), but the individual water users can, officially, not influence this supply nor is the supply 'matched' to specific crop water requirements. This is alleged to cause ineffective and inefficient water use.

Merriam (1992:147) stresses the need for flexible water scheduling according to crop needs: "*Rotation irrigation schedules fixed in frequency, rate and duration inhibit management capabilities, force inefficient use of water and labor, reduce crop production, limit the effective use of rainfall, and frequently relate to higher water table and drainage problems*".

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[1] Water allocation forms a part of a water right. See section 1.5.2.

And Goussard (1996:265): "*...equity-based delivery scheduling is obviously inconsistent with crop-based and water-saving irrigation practices.*"

In irrigation systems with volumetric water allocation and scheduling the supply is matched with the demand. This can be done basically in two ways: either from above (top-down) in a bureaucratic way, or on request by the water user. The Gezira irrigation system in Sudan is an example of imposed allocation. Water supply is roughly adapted to the crop water needs of the imposed cropping pattern, but individual farmers do not have any official means to adjust supply to the actual demand of their crops (Plusquellec 1990). This is volumetric water control, but not the kind referred to by the promoters of volumetric control. The bureaucratic assignment of precise volumes in Gezira and similar systems did not work. If decisions on water allocation and scheduling are decentralised to the farmer level, more locally specific circumstances can be taken into account. If the water users can adapt the water supply to fit their production strategies and actual crop water needs water will be used more effectively. For example, farmers know that their crops are extra vulnerable to water stress during flowering. To prevent over-use the water should be charged by volume.

Some experts think that volumetric water allocation (on request) in poor countries in irrigation systems with many smallholders is too costly, because of: over-sizing of the infrastructure; difficulty of organising on-request scheduling; too expensive infrastructure and lack of well trained staff (Horst 1996, 1998 and 1999, Mangano 1996).

The plea for implementation of volumetric allocation seems rational from the viewpoint of increasing of technical water use efficiency. However, several aspects of irrigation water allocation are disregarded. Water rights were created in historic political-economic processes reflecting social power relations and adaptation to local agro-ecological conditions and technology development. Volumetric water allocation and pricing might cause social differentiation (only the rich can buy water), and reduction of water use efficiency at river basin level (see Seckler 1996). Water allocation is an act of political choice with important implications for the livelihoods of the stakeholders.

Water allocation works through the control over the water source. This control is based on legitimacy in combination with coercion. Even if volumetric water allocation is practised, it are never exclusively 'market-mechanisms' that regulate the water allocation, instead, allocation is governed by a combination of co-operation, competition and regulation. In an irrigation system there is a dynamic process of adaptation between demand and supply based not only on physical availability of water (rainfall, water storage in reservoir and river discharges), but also on the differentiated access of farmers to this water. Even if market-like incentives are in place, like charging per volume, regulation will play an important role. For example regulations to limit the number of farmers allowed to request water, and to limit the maximum volume of water to be requested in water scarce periods (to allow a 'fair' allocation of water). Also co-ordination among the farmers and between the farmers and the irrigation agency or WUA will play an important role. Co-ordination will be necessary to plan the cropping seasons and to establish the Irrigation Service Fee (ISF). Social control on different levels in the system will play a role to guard that allocation to the different stakeholders is within accepted limits. This social control involves access to information and social power.

Therefore, both the simplistic views in favour and opposed to volumetric water allocation are not sufficient to understand the practice of volumetric water allocation. If it functions at all, this will not be because of equal competition in a market for water. It will, instead, be a dynamic process of regulation, co-ordination and competition. In Chapter 2 the history of water rights and allocation is presented and in Chapter 4 the present day allocation and scheduling is analysed.

Volumetric water distribution

To be able to distribute water in precise quantities, to precise locations, at the right time, requires a high degree of technical control over the water flows. In literature on the delivery performance of traditional open channel irrigation systems it has been shown that precise volumetric water distribution is very difficult to achieve. Due to unsteady flow and unpredictable inflow it is very hard to operate a system with constantly fluctuating flow targets (Plusquellec *et al.* 1994). Many experts, therefore, suggest that modernisation of the irrigation infrastructure is needed. There are different technical options for such modernisation. One option is conversion to a pressurised buried pipe system (Van Bentum and Smout 1994). Another option is automation of the operation of control structures, be it by upstream or downstream control (Zimbelman 1987, Ankum 1992, Plusquellec *et al.* 1994). Many stress the need for more flow measurement structures (e.g. Lee 1999)

Horst (1996 and 1998) is of a different opinion. In low-income countries automation of control or pressurised systems are too expensive: both in initial investments as in operation and maintenance. Thus, simple technology should be used, even if that would mean a delivery to the field that is not completely according to the crop water requirements. Horst suggests using proportional division weirs. These divide the water more equitably and transparently and require very little (skilled) labour.

The critique of Horst on the ideas of the 'modernisationists' is correct, but underestimates the institutional capacities, knowledge and skills of local organisations and their engineers and gate operators. The question is how to analyse the interaction between the irrigation technology, the available resources, and the social-economic and institutional environment. To understand the actual performance of the operation of the infrastructure, both the institutional as well as the technical side and their interactions should be analysed.

However, thinking only from the technology itself leaves aside some important issues that are primarily institutional. Of course, the physical structures themselves still play a role in water distribution. However, to understand why the operator performs his[2] duties as he does, it is essential to understand the internal and external incentives faced by him. The accountability towards the users, and the monitoring and sanctioning from his chiefs are crucial institutions. Also the power (legitimacy and/or coercion) of the irrigation agency or WUA, and the social control among the water users themselves, to monitor and effectively sanction water theft and unauthorised changes in the infrastructure are important in understanding water delivery performance.

In Chapter 5 a more elaborate and practical analytical framework will be presented of the technical and social factors shaping water delivery. Then the water delivery performance of the systems at different levels is assessed. The flow measurements are compared with the

[2] Here only the male form is used because to my knowledge gate operators in Peru (and in the rest of Latin America) are always male.

official schedule to see if the WUAs are able (and willing) to deliver the water as scheduled. The reasons behind the performance are analysed according to a framework, which is based on the more general notions presented above.

Volumetric payment for the water delivery service

According to the World Bank (1993:49-59) charging the right price for water is important: "*For irrigation, as for domestic and industrial use, prices reflecting opportunity costs are desirable, but cost recovery fees that ensure financial viability of water entities are a more realistic immediate objective.*" Perry (2001:2) adds a social equity objective to the full cost recovery pricing: "*Where charges are low, or not collected, the beneficiaries of irrigation - who typically are a privileged group within the agrarian sector - receive their service at the expense of the economy in general.*" However, Perry finds it even more important to charge for irrigation water to encourage productive and conservative use of water.

This is also stressed by Repetto (1986:14): "*In most public canal irrigation, water charges are tied not to the amount of water farmers use but levied on the basis of the area irrigated, with some rate differentiation according to crop and season. Using more water on a given acreage costs the farmer nothing. (...) In public irrigation systems, then, there is a chronic excess demand, and use is limited by ration, not by the balance of costs and on-farm benefits.*" And FAO (1996:27): "*The importance of pricing and other incentives that encourage farmers to adopt efficient water-use practices depends on the relative value of water. When water is plentiful, it does not pay to invest in costly monitoring devices and pricing systems. On the other hand, if water supply is scarce, then it becomes worthwhile to measure, monitor and price water. Today, water is indeed scarce in many parts of the world and underpricing has caused serious misuse of water.*"

As Perry stated, in addition to the prevention of over-use in an 'on-request' system, volumetric water pricing can enable the recovery of the costs of the delivery of water (although cost recovery can of course also be done with area-based fees). Cost recovery can relate only to the Operation and Maintenance (O&M) costs, or also include the construction and rehabilitation costs. Both are involved in 'full cost recovery'. As IMF and World Bank impose their Structural Adjustment Programs on borrowing countries, these countries see themselves obliged to cut in government expenses (see World Bank 1993). In many countries this has led to Irrigation Management Transfer (IMT) (also called 'turnover') policies in which farmer groups operate and maintain the irrigation systems they use, but also have to pay for the costs (Johnson *et al.* 1995). In the last couple of decades a considerable number of countries have turned over irrigation systems to WUAs, including the Philippines, Sri Lanka, Ethiopia, South Africa, Turkey, Mexico, Colombia and Peru (Vermillion and Sagardoy 1999). After turnover the users can themselves agree on the water price, this might be set too low to be an incentive to conserve water and also be too low to have sufficient financial means to execute a sufficient O&M program[3].
In most urban domestic water supply systems an 'on-demand' system is used. In most high-income countries the consumption is measured at the entrance of the house and the user pays

[3] It is interesting to note that Vermillion and Sagardoy (1999:82-Box 10) use an example of a turned over system in the Coast of Peru to illustrate the problem of water users agreeing to too low charges and thus cannot operate and maintain their system well. Chapters 4 and 5 will show that in the two irrigation systems studied operation and maintenance was executed well. Chapter 6 will explain more about the price setting.

a fee according to the volume of water used. However, also some irrigation systems work with meters: the Sinistra Ofanto irrigation system in Italy (Lamaddalena *et al.* 1995), Riegos de Levante in Spain (Van Bentum 1995), and the Maricopa-Stanfield Irrigation and Drainage District (MSIDD) in Arizona, USA (Clemmens *et al.* 2000).

Nevertheless, many experts have profound doubts about the usefulness and feasibility of volumetric pricing of irrigation delivery services. The doubts can be subdivided into two categories. First, there are arguments on why charging per volume will not increase the efficiency of an irrigation system. Second, there are the reasons why volumetric charging is not possible in a large-scale irrigation system with many smallholders in low-income countries.

Why (if it is technically possible) would volumetric charging not help to resolve the poor performance in the irrigation sector? First, the price elasticity for irrigation water is quite near zero. That is to say that with an increase in price per unit of water the farmers would not request less water. This can be understood by considering two arguments. The farmers need to supply a certain amount of water or else the crop will fail completely. Crop failure is a terrible drama for a small farmer, (s)he will have no returns to all the investments done (labour, seeds, credit, etc). The other argument for a low price elasticity is that even if the charge is low, or not according to volume, still a farmer has labour costs to apply the water on the field when water comes in turns that have to be co-ordinated and handled in the field. Thus extreme over-irrigation is already halted by the fact that irrigation turns never come free of costs for a farmer. However, in case of continuous flow to the field it saves labour to over-irrigate.

Second, when water supply is insecure, water is hoarded to prevent risk of yield loss due to water stress (Wade 1990). Also Lamaddalena *et al.* (1995) found that farmers prefer to over-irrigate to secure sufficient water in case water can only be requested during certain 'service windows', even if these service windows only close two weeks and there is no limit to the volumes to be requested during the service windows.

Third, farmers might feel the traditional amount of water allocated to a certain plot is an historic right and should not be subject of market mechanisms (Bauer 1997, Guillet 2000).

Fourth, irrigation water can be a substitute for labour. Wolf *et al.* (1996) provide an example from the Jordan Valley where drip irrigation used more water for the same crop as compared to traditional surface application methods. The drip was not installed to save water, but to save labour. In the same way water users might be willing to use more water than needed by the crop in order to save labour in weeding, land levelling or water application. Even if they have to pay per volume of water, as long as the extra costs for the water are less than the labour (and other input) costs saved.

Why is it not always feasible to implement a payment per volume (even if it would increase efficiencies)? Moore (1989) gives four reasons why volumetric payment is not possible in large-scale irrigation systems in low-income countries (Moore refers specifically to Asia). First, the water users in most systems cannot request water. Second, irrigation water is rarely distributed according the schedule, this is due to unpredictable and variable availability from the source and problems in the management of the distribution of the water. Third, many farmers do not have a direct intake from a canal, they receive water from their neighbour, and with saturated soils where rice is grown an individual farmer cannot be excluded from the water service. Last but not least, measuring water flows to all individual plots is too costly.

In this research a somewhat different approach will be taken to analyse the charging and recovery of Irrigation Service Fee (ISF). It does not disregard the effect of volumetric charging on water saving by water users under certain circumstances, but also does not disregard the counter arguments that it can be relevant under certain conditions. However, it argues that in the first place charging should be analysed in terms of social power. The setting of the fee and spending of the funds is matter of negotiation and power struggle. Also the recovery of the fee depends on the power of the irrigation agency or WUA to enforce the recovery the ISF. This power is related to ways to coerce the payment in combination with the legitimacy of the ISF as perceived by the water users. The most logical means of coercion of payment is by denying water in case of non-payment. But also stealing of water from the canals and use of drain water are to be checked by the service provider. If the water users perceive the ISF as legitimate and fair, it becomes easier to collect the ISF. The legitimacy of the fee is increased when the setting of the fee and the spending of the money are transparent and when the water users are able to influence the setting of priorities in the spending of the fees. The setting of the ISF and the fee recovery are subjects of analysis in Chapter 6.

1.5.2 Irrigation systems as sociotechnical entities

The above elaboration and analysis of volumetric water control stayed close to the subject itself. It started from the discussions in literature grouped according to the three dimensions of volumetric water control. However, to gain a more profound insight in the performance and organisation of volumetric water control more abstract and general analytical tools are needed that combine technical and social elements of analysis. In this and the following sections some analytical tools will be outlined. We will start with the more general notion of irrigation systems as sociotechnical entities.

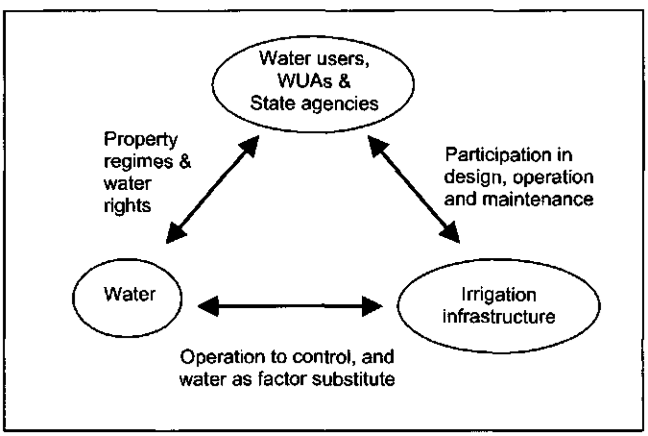

Figure 1.2: Relations between water users, water and irrigation infrastructure (adapted from Mollinga 1998a:16, Figure 2.1)

Irrigation systems are sociotechnical in nature (Uphoff 1986, Kloezen and Mollinga 1992, Mollinga 1998a, Vincent 1997 and 2001). Irrigation systems cannot be analysed as pure technical systems nor pure organisational entities. The space and time dimensions of water distribution and water use have technical and social, economic and organisational aspects that cannot be understood by one discipline only. Irrigation encompasses irrigation infrastructure, water, water users, water users' organisations and governmental agencies (see Figure 1.2). This thesis will look at the sociotechnical processes shaping the interactions between these different components.

Property regimes and water rights

Property regimes define ownership and they comprise principles, policies, and rules by which disputes over property are to be resolved and by which property transactions may be structured so that disputes may be avoided. Natural resources like river water and mineral oil are often state property. State organisations can then allocate use-concessions to users, or keep more tight control and organise a bureaucratic way to allocate resources directly to users. Land is often owned privately. This means titleholders to land can sell it. However, land and water resources can be governed also by other property regimes, like open access or communal ownership. Property regimes influence the control groups in society can have over the resource. State regulation is important, not only for state-owned resources, but also for privately or communally owned resources.

Water rights are concessional or private entitlements to use of water (both at the level of groups of users and individual users). Water rights define relations of (potential) water users vis-à-vis each other regarding the use of a particular water source. Water rights can be seen as bundles of related rights and obligations. They determine who (or in some cases what land) is entitled to what amount of water, at what time, at what place, under specific conditions and against certain obligations (like fee payment and labour contribution to maintenance) (Von Benda-Beckmann *et al.* 1996, Zwarteveen 1997, Gerbrandy and Hoogendam 1998, Boelens and Hoogendam 2002). Water is in many places a scarce[4] and contested resource. This means that water rights exclude potential users and therefore are often the subject of struggle.

In this study property regimes and water rights are important in several ways. In Chapter 2 the history of irrigation institutions show a shift in property regimes from (pre-Inca) State ownership to private (*hacienda*) ownership, to State ownership, and recent discussions of a switch back to private ownership. It also shows the power struggles involved in confiscation and creation of water rights throughout history. In Chapter 4 the bureaucratic (and political) assignment of water titles and specific volumetric water allocations is analysed. The question

[4] Water scarcity is a relative notion. It depends on the relation between water demand and supply. Planning of the demand is always a response to the expected supply. Two examples. First, a community of irrigators will try to balance land with rights to be irrigated (and crops to be grown) in relation to the available water. However, even if the supply and demand are on average in balance there will be wet and dry years resulting in temporary shortages or abundance of water. Second, in government planned and managed irrigation system the balance between supply and demand might give more problems. The protective irrigation systems in India give a clear illustration of the problems arising when the crops in the command area are planned to receive only a part of the crop water requirements (Mollinga 1998a). This is a structural situation: the command area is permanently over-extended. Also in systems that had a good water balance, this balance might change due to increase of command area, increase of cultivation of high water consuming crops, and/or lesser water availability due to climate change, reservoir siltation or increase of upstream use of water by other irrigation systems or other sectors.

here is to what extent 'market-mechanisms' influenced the actual water allocation. On the one hand the allocation was bureaucratic. A public organisation controlled the access to water entitlements and the maximum volume to be used according to authorisation of certain crops to grow. On the other hand, as water users in Chancay-Lambayeque paid a fee according to the volume of water requested, a 'market-incentive' was introduced. The question was whether or not the incentive was strong enough to bring about a reduction of water use per hectare and thus improve the water use efficiencies and productivity of water.

Water and irrigation infrastructure

Levine (1980), Keller (1986) and Uphoff *et al.* (1990) provide some concrete relationships between water and irrigation technology. For example, Uphoff stresses that relative water scarcity influences the need and possibility to organise an efficient water distribution. With extreme water scarcity or extreme abundance water users will not be interested to put much effort in organising themselves to allocate and deliver water. Keller shows that low relative water supplies require more costly infrastructure and institutions to control the water deliveries, or in his words: stretching a thinner membrane of water over a larger area causes more social tensions. Levine stresses the fact that in inefficient irrigation systems excess water often is a factor substitute. The extra water is used to make the water distribution easier: water is a substitute for management input.

Irrigation infrastructure is like a 'tool' to control water and effectuate the water delivery plan. However, the infrastructure also transforms the water from an 'untamed natural resource' to a service delivered at the field of a farmer. The infrastructure can do this only because it is operated and maintained in a certain way. The degree of labour and skills required for operation and maintenance depend mainly on the type of conducts and division structures used. Operation will be the main focus of Chapter 5 on volumetric water delivery.

It should be stressed that technical and environmental factors in irrigation systems not only include water and the irrigation infrastructure: also soils, climate and crops possess physical properties that are crucial in understanding the functioning of irrigation systems. Crops require certain amount of water at certain times. Crop growth is related to minimum and maximum temperatures, defining the timing of the crop production. In arid zones salinity is an important hazard. Salinity is influenced by water quality, soil properties, water supply and drainage. If natural drainage is insufficient waterlogging might cause 'secondary' salinity. A drainage system of primary, secondary, tertiary and field drains might be constructed to evacuate saline water.

Participation of government and users in management of irrigation systems

The organisations that manage large-scale irrigation systems are complex entities. Usually both governmental as well as users' organisations are involved in irrigation management. In the top of the hierarchy public agencies can be found, and users' groups are supposed to manage lower levels of the system. The exact configuration of the management entity depends on the degree of decentralisation. In some systems the joint-management only allows users' control in the tertiary blocks. In the North Coast of Peru users' organisations were in charge of the secondary and main systems as well. The relation between the different organisation is complex because different domains of authority do not coincide necessarily with the levels of the irrigation system. For example, in Peru the governmental organisation at system level defined the water allocation at field level, but did not control the financial management nor water delivery of the water users' associations at tertiary, secondary nor main level.

Participation in decision making in the management is about control and about power. Usually a limited participation in the higher levels of the system is legitimised by reference to the expertise needed to make decisions at these levels. In that way an elite of experts can fence itself off from user participation by claiming exclusive knowledge and skills (Waller 1996). In the case of volumetric water control the claim of required expertise might be even higher than in systems with share-based allocation.

However, evidence presented in the next chapters shows that participation of users was fostered at main system level in the studied large-scale irrigation systems. It was neither an expert nor a local elite that took power after the Irrigation Management Transfer. Also, mechanisms were in place to enforce accountability of the water users associations towards the water users.

Participation in decision-making regarding the irrigation technology can be in the design, the operation and maintenance. Uphoff (1986) provides a sort of three dimensional check list in the form of a cube presenting the activities involved in management of irrigation technology. Two dimensions are relevant here: infrastructure has to be designed, constructed, operated and maintained. This requires decision making, resource mobilisation, communication and conflict management.

In the next sections some analytical concepts will be worked out to help understand the complex organisation of (volumetric) water management in large-scale irrigation. The concepts help analyse the nature of irrigation technology and the nature of the complex relations between the organisations of the joint-management entity.

1.5.3 Irrigation technology

Technology is the hardware (artefacts) and software (knowledge, skills, organisation and information) used by people to reproduce and transform material and social reality (Mollinga *et al.* 1987). Two very different theories help to understand the link between social structures and physical objects: the 'social construction of technology' (SCOT) theory and the 'actor-network' theory.

The SCOT theory looks at the social construction of technology, the social requirements for use and the social effects of technology (MacKenzie and Wajcman 1985, Bijker 1987 and 1993, Winner 1993, Hård 1993). Irrigation technology is a social construction in the sense that is was developed (designed) by actors with certain interests, therefore it has certain social and technical requirements for use. Irrigation technology has different consequences for different groups of people (Mollinga 1998a). The first part, the social construction, will get attention especially in Chapter 2 on the history of the irrigation technology and the water rights. The requirements for use will be part of the analytical framework developed in Chapter 5 on the water distribution. Here the attention is on institutions needed to control the technology for VWC. The social consequences of the irrigation technology will get attention in Chapters 5 and 7.

The actor-network theory is a completely different type of theory compared with the SCOT theory. The ontology and epistemology of the actor-network theory start from the radical viewpoint that humans and material artefacts should be analysed in equal terms. In the presented research this radical ontology and epistemology are not used. However, some minor notions taken from the actor-network theory are considered useful.

The actor-network theory uses the idea of a seamless web in which objects and humans play their roles of actors with strategies and as intermediaries (Law 1992, Latour 1995). The idea of looking at the 'control power' (or 'capacity of translation' as Law and Latour call it) of both artefacts and humans is at the heart of the actor-network theory. This is interesting as it focuses more than the SCOT approach on the use of artefacts (and humans) in controlling both things and humans. Because of its 'symmetry' in approaching artefacts and humans the idea of 'substitution' between artefacts and humans becomes easier to analyse. The control over water - distributing it through a network of open canals – is executed by humans (operators and water users) and by artefacts (canals and gates). Both humans and artefacts are needed, but one can be partly substituted by the other. Another example is: on the one hand one can have padlocks on gates to stop tampering with the gates and on the other hand one has rules, monitoring and punishment of theft. In this example the padlock probably is not a very serious physical barrier (most are quite easy to break), but leaves a clear trace of a breaking of a rule that will facilitate punishment.

Callon *et al.* (1986) introduce another useful idea to combine the social and physical forms of control: 'obligatory points of passage'. The obligatory points of passage make monitoring and sanctioning a lot easier. If somebody has to pass through a certain point of passage the control (in space and time) can be concentrated there. The points of passage comprise both physical and institutional elements. An example can be given from the public administration of Peru. The registration of persons and where they live is incomplete. Few pay the municipality and traffic taxes. However, the regional and national elections are obligatory. You can only register as a voter after you have paid your taxes and fines. The only possibility to escape from this 'obligatory point of passage' is to refrain from voting. This you can do, but has severe consequences, because the proof of your voting is needed with every (however small) service you need from any government organisation. Thus many social needs (like: register property, register an official business, being candidate for elections of any official organisation) require the proof of having voted, which in turn requires paying your taxes and fines.

1.5.4 The nature and functioning of the complex irrigation management entity[5]

As described above, the entity that manages a large-scale irrigation system can be seen as a complex entity that exists out of different public and users' organisations. Organisations are relative stable social units with broad collective objectives. The rules, regulations, hierarchical chains of command, control mechanisms, routines, and rituals, practised in the organisation form an internalised structure that both constrains and enables the internal functioning of the organisation.

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[5] Much of this section is based on insights from the useful book on different theories on organisation written by Reed (1992).

There is an important difference between institutions and organisations: "*Institutions are the social rules, conventions, and other elements of the structural framework of social interaction*" (Bardhan 1989:3). Examples include: marriage, land tenure arrangements and law of inheritance. Organisations are a special sort of institutions. They are actual structures of recognised and accepted roles and functions in specific domains and territories. Examples of organisations include: a water users' association, an NGO, an international research institute and a local informal credit association. The structure exists because it is reproduced every day by the members of the organisation. The structure exists also somewhat independent from the individual members of the organisation in the sense that new members will (have to) adapt their activities to the existing structure[6] and therewith will sustain it (socialisation mechanisms will work continuously, also on 'older' members). The structure is also encoded in all sorts of artefacts, like the lay-out of the building the organisation works in, the formal manuscripts and forms the members use, the software they use, and the communication utilities they have installed.

Although organisations structure the behaviour of its members, the individuals making up the organisation have a certain room for manoeuvre, which they use to pursue own strategies and to negotiate. All members have different (and possibly conflicting) interests based on their position, tasks, norms and values. As all members depend to a certain degree on other members to fulfil their personal goals, the members use their bargaining-power to negotiate. In this context, power is approached as a capacity to control the course of events and the actions of other actors so that the negotiation process reflects the preferred outcomes of certain individuals and groups over others[7]. Power resources and relationships vary over time, place and problem.

Social power also is important to understand the relations between different organisations in the irrigation management entity. Also here power is related to dependency. In some situations the dependency is mutual. For example, a representative in the board of the WUA depends for his support in elections on the water users. The water users depend on the representative for having access to water and information.

Power automatically generates countervailing powers if the legitimacy of the authority is decreasing (Clegg 1989). This resistance should be distinguished from free-riding behaviour (the latter being opportunistic the former being structural). The resistance can be 'small' (the 'Weapons of the Weak' of Scott 1985) or the resistance can build up to collective struggle against the sitting power holders.

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[6] This structure can be seen as the 'rules actually used'.

[7] Lukes (1974) offers a framework of three dimensions of power to encompass the different layers of direct and less direct power effects. The first layer is the most simple one where one person or group of persons has direct power over the behaviour of another person or group: "*A has power over B if A can affect the incentives facing B in such a way that it is rational for B to do something he would not otherwise have chosen to do. The incentives of B are affected by A mainly through the offer of a* reward *or the* threat *of a penalty or some combination of a threat and an offer.*" (Taylor 1982 cited in Bardhan 1991:266, see also Weber 1947). The second layer of power is less direct. It can best be described as 'Setting the agenda' (Bachrach and Baratz 1962). People anticipate the chance they will have in raising an issue and are sometimes directly hindered in raising an issue. In that way many issues never come on the agenda of discussion or open conflict. The third dimension is even more indirect. It is the power of the generally accepted values and norms in society: the hegemonic ideology. Neo-Marxists claim these norms and values favour capitalists. "*It is the supreme exercise of power to get another or others to have the desires you want them to have ... to secure their compliance by controlling their thoughts and desires*" (Lukes 1974:23).

Irrigation management entities in large-scale systems are complex organisations because of several reasons. There is a hierarchy of different tiers in the organisation, in which each tier has influence in different domains of the irrigation system. The domains have fuzzy boundaries and are partly overlapping. The domains not only refer to certain physical parts of the infrastructure (main canal, tertiary canal, etc.): different groups also have specific decision making power over a limited number of affairs. The domains of authority of the organisations do not necessarily coincide with the level of the organisation in the irrigation system.

To further analyse the complex irrigation management entity we elaborate on three related themes: (1) Domains and rules, (2) Participation in decision making, and (3) Accountability.

Domains and rules

Domains form a field of social interaction and have both territorial and social boundaries. (Van der Zaag 1992, Villarreal 1994, Mollinga 1998a). Relations and rules in a domain relate to certain specific topics. The authority and social power an individual can exert depends on the domain. Within a domain some individuals usually have more influence than others (Manzungu 1999). Different domains can be identified in the complex water management entities. The organisational structure is closely related to the levels and hydraulic units of the irrigation system, for example main system, secondary canal, and tertiary block. However, organisations might have different authority at different levels according to the specific issue at stake. The domains are partly overlapping, and have fuzzy boundaries. For example, the head engineer of the *Junta de Usuarios* manages the main system. The domain of management thus is the main system, but by controlling the main system he also controls how much water flows to each secondary canal. The division of this water among the tertiary canals is out of the control of the head engineer.

Rules are a set of sanctioned prescriptions of institutions and norms. Rules are used as means to shape social interaction, but actual concrete social relationships and behaviour are not determined by rules alone. A diversity of normative frameworks, together with interests derived from economic, social and material positions influence the actual behaviour of people. People are actors that actively design strategies within the constraints and possibilities perceived by them. The strategies can be geared to co-operation or to competition[8]. Both types of strategies are structured and guided by rules.

Inside the complex irrigation management entity one can distinguish two types of rules. One type is a means to regulate daily management and practical operations. The other type are rules used in governance of the organisation (Tang and Ostrom 1993, Geijer *et al.* 1995). Governance refers to the structuring of access of people to positions with decision-making

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[8] What drives people and what makes them decide to opt for either competing with others or co-operate with them is subject of debate. Neo-liberal economists start with individual profit maximisers, simply assuming preferences translated to money reflect their interests. Others have criticised this simplistic idea and argued that altruism or at least less self-interest-centred motives are important (e.g. Levine 2000). They also argue that behaviour in general is much less 'rational' and 'calculated' than neo-liberals assume. Also their choice between co-operation or competition is more complicated than can be simulated with a 'prison dilemma game' (see Ostrom 1990 for the very influential New Institutional Economics approach based on these type of decision-games, and Moore 1990 and Mollinga 2001 for critiques). It is not just 'transaction costs' - like lack of information - that makes co-operation (or collective action) fail to come about. Tradition, intuition, affectivity, expected coercion, enforced regulations, lack of social power, leadership abilities, all influence the decision between co-operation for collective action and competition.

authority. Rules on governance establish how the structures of authority are defined and how representatives are elected. They specify the rights of the group members vis-à-vis each other and vis-à-vis the group or group representatives. Rules on daily management give principles and prescriptions on operational routines and decision taking on minor issues.

Domains can be analysed as being 'semi-autonomous fields' as defined by Moore (1973). The boundaries between different semi-autonomous fields are permeable. Rules from outside a field are used inside the field by groups as means to help materialise their interests in negotiations, disputes and conflicts. For example, national law can be used by actors in the social fields. The law is therewith transformed and used in the social power relations between the actors in the field. An example: water users that are organised well on the basis of self-arranged co-operation can enforce accountability of their leaders with the help of government rules. They can do that by using the authority of the local irrigation office of the Ministry of Agriculture to enforce certain rules in the National Water Law that prescribe the behaviour of the board members in the WUA. (See also for example Von Benda-Beckmann 1989 and 1992 for 'law as a resource in social struggle').

Stakeholders justify claims, for example, to gain access to water or access to participation in decision making by referring to certain rules. These rules can be State law[9], customary law or local regulations (none of them monolithic normative bodies) (Von Benda-Beckmann *et al.* 1996) (see also the idea of forum shopping, Von Benda-Beckmann 1981). However, also generally held norms and values and technical arguments are frequently used to justify certain claims. In negotiation, disputes and conflict there should be made a distinction between on the one hand conflicting interests and on the other hand conflicting normative frameworks or different interpretations of the same normative framework[10].

However, rules are not only used in bargaining and conflict situations where stakeholders use them to justify claims. Persons and organisations with authority enforce compliance of rules. Rule enforcement in water users' association (as well as in agency managed systems) has received much attention. Major issues are: water theft, payment of the Irrigation Service Fee (ISF), contribution to the labour for maintenance, and 'perverse' activities like rent-seeking and bribing.

It is important to make a clear distinction between 'rule violation' and 'conflicts'. Breaking of a rule occurs to acquire a relative better position (e.g. more water) without confrontation or conflict. A (water) thief does not contest the legitimacy of the existing rules. The breaking of the rule is opportunistic (free-riding) behaviour, and the offender will in most cases comply with the punishment upon being caught (if not, a breaking of a rule might become a conflict). Many acts of breaking of rules on all levels in the irrigation system go unnoticed. Only when behaviour is monitored can breaking of rules be detected. Monitoring can happen on a routine

[9] Government organisations themselves have specific interests in making of rules. The State is not neutral to the regulations for the water users. It is not just regulation for the sake of peace and efficiency. Particular interest groups may see their interests represented by State regulations, but also the different bodies in the (national and local) ministries have particular goals of their own: like gaining control over money flows, and maintaining relative autonomy (see Rap *et al.* (forthcoming) on the case of IMT in Mexico). Also the WUA is not just a body of representatives of the water users. The board of the WUA has goals that represent the interests of certain water users and has goals of its own.

[10] Rules are interpreted differently by different (groups of) persons. Rules might be quite abstract principles that allow many interpretations in concrete situations. Rules are also transformed locally to 'fit' local circumstances.

basis (policing) or can happen with specific reasons beyond the offence itself driving the 'policing'[11]. In an irrigation system much of the routine monitoring is done by the water users themselves. The water user with a water turn will monitor the delivery of the water to her or his field. Upon detection of a water theft the water user might settle the offence her or him self or go to a higher authority. Punishment of rule violation also needs an authority to impose the punishment and mechanisms of coercion to enforce the punishment.

Punishment of rule violation should be distinguished from disputes and conflicts. Conflicts are here seen as social processes in which actors explore behaviour that mitigates against consensus and co-operation in finding new workable practices. Conflicts occur when persons want to attain a relative better position by confronting an existing situation with a claim in their favour. To make the confrontation successful they will legitimise their claim with certain arguments and/or refer to certain authority. Sometimes the conflict can involve breaking of rules. Conflicts can also be part of a (political) bargaining process. The parties might want to influence the allocation of scarce resources (water, subsidies,..) or might want to gain political influence. Conflicts can also arise about the procedures to make rules. Both in case of a bargaining process or in a rule violation, the lack of an authority (be it one of the involved parties or an outside party) to enforce a decision or punishment makes conflict resolution more difficult. Disputes are here seen as less strong confrontations between opposing parties. In case of disputes the parties (still) want to discuss and negotiate. The parties can come to an agreement themselves or might need only some form of arbitration or mediation by a third party to solve their dispute.

Finally, the terms 'authority' and 'legitimacy' have been mentioned several times and need some further clarification. Social action of actors is influenced by structuring forces. The amount of determination by an external force can range from a weak incentive (leaving many choices open to the actor) to a complete physical force (leaving no choice at all). In this respect it is useful to define legitimacy and authority, and different degrees of coercion.

Legitimacy is the extent to which social, technical or political norms are accepted. Legitimacy may refer to for example political systems, projects, actions, or expert systems. It is distinguished from authority, which is the accepted role a person has to exert power (Heywood 1994). Decisions taken by a person (or organisation) with authority are perceived as legitimate. Power is exerted in basically two ways: by enforcing policy, rules and decisions that are perceived as legitimate by the subordinate actors, or by coercion. Governing is easier (and less costly) when people accept the legitimacy of rules than when the rules have to be enforced by coercion. Legitimacy in the case of the governing of the boards of the WUA is associated with elections of the members, the national water law, and most importantly the opinion of the water users that the members of the board are managing the irrigation system well. This latter argument implies that in case the water users have the feeling the board is not doing well according to local expectations, the board loses its authority.

Coercion can have different degrees. For example, a television commercial influences consumer choices, but the degree of steering is low (and mostly unconscious). Incentives have a higher degree of steering. Incentives are rewards and sanctions (mostly monetary but not

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[11] Sometimes monitoring of rule violation is done for 'political' reasons. Certain stakeholders might benefit if they could detect a breaking of a rule by an 'opposition' fraction. They do not just look for any offences on a routine basis, but will actively look for breaking of rules by certain persons.

necessarily so) that influence choices of actors. In neo-liberal economics the term 'incentives' is used to explain behaviour of actors in the labour and consumer market. Neo-liberal economists stress the voluntary aspect of incentives. The employee or consumer has still important room of manoeuvre. However, the degree of coercion in many cases is bigger than assumed by neo-liberal economics. For fear of losing a relatively good paid job an employee might be forced to comply with all sorts of formal and informal rules (e.g. work overtime). If alternative employment is easy to find the compliance with the rules might be voluntary, but often it is not. However, also the employer is often forced to accept certain behaviour of its workers. In fact all social relationships involve some degree of coercion. "*Coercion (...) arises from constraints which individuals have to take account of in realizing their goals. Coercion does not prevent people from making choices although in its more direct forms (...) it may severely limit these choices.*" (Hoffman 1995:7).

Coercion can be illustrated with the before mentioned 'obligatory points of passage'. Obligatory points of passage consist of a network (or structure) of technical, environmental, economic and social elements. Together they form a mechanism of enforcement that leaves little room for manoeuvre for the 'target' actor. The degree of coercion in obligatory points of passage is quite large. The coercion is not a physical force that leaves no choice. However, non-compliance is hard to achieve (costly) and has severe consequences. The obligatory point of passage comprises relative passive constraints and relatively more active processes of coercion.

If rules are perceived as legitimate the enforcement of the compliance is easier to enforce. However, even if the rules are perceived as legitimate often a certain degree of coercion is still necessary for compliance (for example: paying taxes). Coercion is related to social power relations. Sometimes higher authorities can be mobilised by one party to coerce the other party to comply with the rules advocated by this higher authority. Sometimes rules are enforced among equals. This is called social control (Black 1984, Horwitz 1990). Mutual control is easier when social stratification is less.

Participation in decision making

The increase of participation of water users in decision making in irrigation management in large-scale irrigation systems has been widely debated the last 30 years (Meizen-Dick 1997). It is argued that management will improve if users can take management decisions that are the outcome of local negotiations between the local stakeholders and based on local knowledge and normative frameworks. For a long time the focus had been on participation of the individual water user in only the management inside the tertiary block in government managed irrigation systems. However, the focus of participation of the users in irrigation management changes dramatically in case of Irrigation Management Transfer (IMT). If the management of the irrigation system is turned over to a Water Users' Association (WUA), in principle, the water users take all major decisions on all levels of the irrigation system. However, internal differentiation among the water users makes that it is often the elite that takes the decisions and the 'common' users still have as little say in the irrigation management as under a government managed system. The WUA-leaders and staff employed by them take over the roles of government officials (Oorthuizen and Kloezen 1995). Waller (1994) argues that elites, together with experts, can easily take control of regional water management as involved management decisions are complicated. Laymen can be excluded by referring to the expertise needed to understand and decide on water management. Hunt and

Hunt (1974) argue that elite involvement in management of large-scale irrigation is necessary for effective conflict management.

There is one important difference between a Water Users' Association and an Irrigation Agency: the Agency is only directly accountable towards the government and the WUA is accountable towards the users and remains also accountable towards the government. The leaders of the WUA are elected and staff can be dismissed if the water users demand that. In principle the water users can draw up the rules of the WUA (within the broader framework of the national law). In contrast, the staff of the Irrigation Agency is not directly accountable towards the users. Staff can only be replaced by pressure on the political leaders (Wade 1988 gives clear examples of this situation).

Decision-making is about having power. Therefore, there is a constant struggle in irrigation systems between on the one hand power-holders (like elected farmers' representatives) and on the other hand groups of 'common water user' who want to participate in decision making. Mechanisms of democratic representation would ensure a certain degree of influence in decision making by the 'common water users'. However, even if these mechanisms function, and farmers' representatives are elected to form boards of the WUA, the conflicts on different visions and interests would not stop. There remains always something that can be called the 'participation dilemma'. Different stakeholders have competing and conflicting interests, different opinions and access to different knowledge and information. Not all wishes can be executed, not all knowledge systems be integrated. If decision making is delegated to a leader or personnel employed by the WUA, this person will face a lot of problems in responding to the different wishes of different stakeholders. Transparency in decision-making and free access to information on water flows and other relevant issues increases the possibilities for participation of 'common' water users in decision-making.

Accountability

Accountability has been defined by the Oxford dictionary (1988:5) as being an "*obligation to give a reckoning or explanation for one's actions*".[12] It implies answerability towards a person or body that has imposed a task or duty. If one party can be held accountable by a second party this later can exercise control over the actions of the first. The exercising of control makes accountability a power relation. Management studies have argued that the end result of creating greater accountability is higher organisational effectiveness (for irrigation see: Uphoff *et al.* 1991).

Smith-Screen (1995:26) states "*Every organisation has many stakeholders, and the levels of accountability by the organization to each stakeholder may differ. When the interests of the*

[12] Accountability can be seen as 'answerability' in general terms. This is how Mollinga (1998b) uses accountability of politicians in India towards water users in large-scale government managed irrigation systems. However, this confuses the 'responsiveness' of the politicians responding to the wishes of the water users (in return for votes) with the more strict idea behind accountability. Malano and Van Hofwegen (1999) use accountability in this much more restricted way. Here accountability implies the enforcement of the agreed service provision to be delivered by the irrigation agency and enforced by the water users. This is how accountability is used in this thesis. However, Malano and Van Hofwegen use the concept of accountability confusingly themselves when they introduce: 'operational accountability', 'strategic accountability' and 'constitutional accountability'. The first being the enforcement of the agreed services, the second and third are defined in this thesis as participation in decision making.

different stakeholders come into conflict with each other, it is the level of accountability of the organization to each group which determines whose interests are to be maintained. (...) being accountable to the members does not mean asking for their permission each time a decision has to be made or accounting for all the resources to the members at all times. What is does mean is that the organization is responsible to the members for the outcomes of all decisions made by the management."

Accountability relations exist between all domains in the water users' association. Not only the boards of the water users' organisation are accountable towards the water users, also the water users are accountable for their behaviour towards the board. Also the government is accountable towards the users and users towards the government. Accountability is often enforced by using 'third parties'. An example of this are 'consumer organisations' that defend the interests of purchasers of certain products or services. The purchaser can enforce a good product because the consumer organisation can mobilise public opinion against a provider in case something is wrong with the product. In the case of irrigation it can be the public media (newspapers, radio stations) that can be used by a group of irrigators to enforce accountability of their representatives. Transparency in management and access to information are crucial to increase relations of accountability.

Accountability can be exerted regarding different issues. Does the organisation perform its core tasks (water delivery), does it handle inputs (money) from users and State efficiently, does it raise sufficient funds, can it cope professionally with crisis and technical and environmental problems? Financial conduct is one of the key issues. Important are both external financial audits (by government agencies) as well as internal financial control through informing the water users about the spending of funds. Water delivery is another important issue. Water users should be able to monitor, evaluate and sanction the service delivery by the water users' organisation.

Finally, there should be made a distinction between participation in decision-making, accountability and responsiveness. Participation in decision making is direct involvement in management. Accountability is the extent to which deviations from an agreed plan can be monitored and sanctioned (and corrected). Responsiveness is the degree to which a service provider permits informed changes in the service provision on basis of preferences of the 'service consumers' (Uphoff 1986). In water management the difference between participation in decision-making, accountability and responsiveness thus evolves around real power of the water users to influence the irrigation agency or board of their water users' organisation.

Implications for the research

The above framework for looking at Water Users' Associations and governmental agencies starts from looking at the relations between and internal dynamics of the organisations. It considers the technical, environmental, social, legal and economic factors that influence the organisations and their performance. It looks primarily at the dimensions of volumetric control: allocation, scheduling, delivery and charging. Actual water assignment, operation of the infrastructure and fee charging and recovery was understood as a result of a complex sociotechnical processes.

For the research it meant that information was gathered on actual behaviour of actors in the different domains. Also the interests of stakeholders and their means to exert power were studied. Cases of conflict and disputes were followed because the claims used by the stakeholders reveal the different normative frameworks used and the outcomes of the disputes and conflicts reveal the relative power positions the different stakeholders have. Actual outcomes of the processes were assessed also in a 'hard' way by measuring water flows and yields.

Table 1.2 givens an overview of the discussions on volumetric water control and the framework used in this research.

Table 1.2: Overview of the mainstream view on volumetric water control (VWC), its critique and the concepts used in this research

Dimension	**Mainstream** (in favour of VWC)	**Critique** (opposed to VWC)	**Conceptual framework used to study volumetric water control in Peru**
Volumetric allocation and scheduling	Efficiency in irrigation should be increased by matching water allocation to crop water requirements (on request of the farmer and with charging based on the volume applied by the farmer). Efficiency will increase automatically through the self-interest of farmers.	Precise allocation is not possible, because top- down scheduling will not work (insufficient data on farming styles and climate) and on request scheduling is too costly to implement with many smallholders in large systems in low-income countries.	Water allocation mechanisms are institutions that have evolved from a process of power struggle. They not only affect productivity (efficiency), but also (in)equity. Allocation works through control over the resource. The power to control comes from legitimacy and coercion. It is not the 'market' that regulates allocation, but a combination of co-operation, competition and (State) regulation.
Volumetric delivery	High-tech hydraulic and automated infrastructure can deliver the right volumes on the right place at the right time according to the schedule.	High-tech will not work in poor countries with less trained personnel. Simple proportional division structures would perform much better.	Control over water based on: Technology (shaped in social process, having social requirements for use and emergent properties) in relation with: *knowledge/skills of, and incentives for, engineers and operators *power to enforce rules to punish illegal water taking * power of the users to enforce compliance of schedule (accountability).
Volumetric charging	It is good to charge per volume because it gives incentives to save water. (also full cost recovery is good, but that can also be achieved with an area-based fee).	Farmers will not face sufficient incentives to save water, because: price elasticity is low, if supply is not reliable water will be hoarded and water is a substitute for labour. The billing of many smallholders, and the measurement of the flows to their fields is too costly.	Power to recover fees (exclude non-payers) > in substitution with: Legitimacy as perceived by users to charge the fee (do users believe money is spent well?), this includes transparency (accountability) in spending and participation in decision taking.

1.6 Research questions

In light of the discussion on volumetric irrigation water management and the specific situation in the North Coast of Peru discussed above the following research questions were formulated to guide the research in the two irrigation systems:

Main research question:

How are volumetric irrigation water allocation, charging and delivery organised, what is their performance and what are the most important technical, environmental and social factors structuring this organisation and performance in the Chancay-Lambayeque and Jequetepeque irrigation systems?

Sub questions:

1. What are the broader historic processes that influenced water control: what are the societal changes and political processes shaping the (power) balance between local and national control, and public and private control?
2. How are the irrigation water allocation and scheduling organised, why, and what are the effects on productivity of water, and water allocation to farming households?
3. How is the water delivery performance to different levels in the irrigation systems, how is the delivery organised, with what infrastructure executed, what is the history of the irrigation infrastructure used and what are its requirements for use (for the operators), what is the influence of the water users on the distribution and how does water delivery affect crop production?
4. What is the financing structure of the irrigation systems, how is the ISF set, how is the ISF recovery organised, what is the ISF recovery, how is the money spent, why did the *Juntas* introduce such charging and how are the production and irrigation strategies of the water users influenced by the charging?

1.7 The research methodology

From September 1998 to May 2000 field research was conducted in two irrigation systems in the North Coast of Peru. As the scope of the research was interdisciplinary, a wide range of observation and measurement methods were undertaken.

1.7.1 The pros and cons of comparative research in irrigation systems

Irrigation management research is mostly done by case study research. In most cases only one case or a small number of cases is studied. This poses special problems (Yin 1984, Lieberson 1992). A case study can be descriptive or in search of more 'hard' causal relations. A causal relation does not have to be deterministic: it can be emergent or 'circumstantial'. In case of the search for causal relations a 'classical' comparative research design can be used. In a research in which two situations are compared, which are equal on all relevant parameters ('context'), but are different on one important aspect (the independent variable), the effect of the independent variable on several aspects (the dependent variables) can be assessed. This 'classical' comparative design is mostly used in laboratory investigations and agronomic field trails. For irrigation studies this design is much more difficult to follow, because two systems will normally be different in many relevant aspects. One way of assessing the effect of an intervention is to do a 'before – after' research. In many cases this is also difficult, because of lack of data on the 'before'-situation and the changes in the context (e.g. water availability, market prices) during the intervention.

Two interesting examples of comparative researches are the study of Geertz (1972) on the effect of climate on irrigation institutions and Burns (1993) on the effect of climate on the functioning of irrigation systems in South East Asia. Both found important differences in the type and management of the systems, but it is not clear if those were only caused by the differences in climate. A lot of other factors might have contributed to the found differences, like: culture, history, and relative prices of production factors. In the Irrigation and Water Engineering Group at the Wageningen University, two PhD studies have been conducted in large-scale irrigation with a 'classic' comparative design. One is the study of two Spanish irrigation systems by Van Bentum (1995) the other is the study of three irrigation systems in the Terai of Nepal by Pradhan (1996). Both studies show the difficulty of comparing irrigation systems: the systems vary on more factors than only the water control technology. Thus, the effect of the water control technology on the agricultural production process (which Van Bentum studies) and on the delivery performance (which Pradhan studies) was hard to determine. Other parameters like relative water availability, crops, and scale of the systems, also influence the effect of the technology. Nevertheless, comparative research can be very useful to assess the influence of certain factors on the functioning and effects of irrigation systems.

In this research a comparison is made between two irrigation systems in the North Coast of Peru. The aim was to assess the effect of the difference in charging for the irrigation service on the performance and organisation of water use. In system one (Chancay-Lambayeque) the water users pay per volume of water used, and in the other system (Jequetepeque) the water users pay a fixed fee per hectare according to the type of crop they irrigate. In Jequetepeque they use more water and have higher yields per hectare, but the productivity per unit of water in Chancay-Lambayeque is higher. However, as in the above-mentioned comparative studies, also in this study the two irrigation systems differ in more relevant aspects: Chancay-Lambayeque is more than twice the size and has less water available than Jequetepeque. Also the storage capacity of the reservoirs is different and the cropping patterns differ also.

Thus, the effect on performance and water productivity cannot be attributed to the difference in charging alone. Other parameters: relative water availability, storage capacity and cropping pattern should also be considered. This does not mean that nothing can be said about the effect of the water pricing. Two research methods help to isolate the effect of water pricing: (1) using 'before – after' data on water use after the introducing of volumetric payment in Chancay-Lambayeque, and (2) looking at different values of the relevant parameters in smaller areas within the irrigation systems. For example, the study compared only the rice-growing areas and the areas that have more or less the same water availability.

Finally, besides the search for causal relations, there is another advantage of using a comparative research approach. This can be illustrated with an example from the research in Peru. In each watershed a water judge (*Gerente Técnico de la Autoridad Autónoma*) is appointed by the Ministry of Agriculture. One of his or her tasks is to judge over water conflicts. In many cases this conflict is between the board of directors of the Water Users'

Association (WUA) and a water user. If the study had been conducted only in the Chancay-Lambayeque irrigation system the impression would have been that the water judge is mostly favouring the board of the WUA, because his decisions favoured the board. In Jequetepeque, however, the water judge often took a position against the board. Thus, although both water judges held the same position and were imbedded in the same institutional setting, their personal attitude made a difference. The advantage is that two cases show more diversity than one case. Therewith, a wider sample prevents 'deterministic' analyses like: "the water judge favours the board of the WUA because he works with the Ministry of Agriculture, which is more closely related to the board of the WUA than to the individual users." Many more examples can be given in the two systems where the same laws and history applies, but different practices can be observed. Thus, comparative case study analysis prevents deterministic tendencies in the description of the cases.

1.7.2 Selection of the case study systems, secondary canals and tertiary blocks

In a comparative study the selection of the case study areas is extremely important because it influences very much the outcomes. A biased selection can have enormous influence on the outcome of the research. However, in most cases insufficient data will be available on forehand to make a good selection. Also practical matters will influence the choice of research site: like distances (travelling time), available data, and willingness of key persons to co-operate.

As was explained in section 1.4, two irrigation systems were selected from the large-scale irrigation systems in the North Coast: Chancay-Lambayeque and Jequetepeque. Within the two systems secondary canals were selected for more intensive study. The main selection criterion for the secondary units was the location (in the middle reach and tail-end). In Chancay-Lambayeque the *Comisiones de Regantes* Lambayeque (middle reach) and Muy Finca (tail end) were selected. In Jequetepeque the *Comisiones de Regantes* Guadalupe and Pacanga were selected.

Within these secondary units, tertiary blocks were selected for a flow measurement programme. Key selection criteria were: average condition of infrastructure, land holding sizes, and location within the system (middle reach). In *Comisión de Regantes* Lambayeque, the tertiary block named 'La Ladrillera-La Colorada' was selected. In Muy Finca, the tertiary block named 'Sialupe-Solecape' has been chosen. In Jequetepeque, in the *Comisión de Regantes* Guadalupe the tertiary blocks 'Farcancillo', 'Granja' and 'Huanabano' were selected. In Pacanga no specific tertiary block was selected.

1.7.3 Observation of practices and informal interviewing

Participant observation was a very important method used to understand the management of the irrigation systems and the farming practices. On most days during the irrigation seasons 1998-99 and 1999-00 field visits were made to the tertiary blocks to observe the water distribution, observe the daily meeting where the water users and the *Repartidor* make the schedule of water turns, observe the crops in the fields (making a land use map) and have some informal interviews with water users. Several times a week I would make appointments with staff at different levels of the WUA and officials of the local irrigation office of the Ministry of Agriculture to conduct semi-structured interviews, obtain records or, as I came to know them better, have some informal 'chats'. Also major events like WUA general assemblies, congresses, and other special events were attended. I wrote down the observations each day and later used the Kwalitan 5.0 text analysis software to order (by key words) and retrieve fragments of the observations in the day's reports.

As stated above a useful way to gain insight into the interests and formal and informal rules used in the management of the systems is to obtain information on conflicts. Therefore, conflicts were followed by interviewing stakeholders and obtaining official documents on rule violations and conflicts both at the level of the government offices ATDR and AACH.

To be able to assess the productivity of water and to check qualitative data from literature and official statistics on farmers' inputs and yields, two quantitative methods were applied. Yield samples were taken in rice fields with a one by one metre square wooden frame. In one field, six randomly selected samples would be harvested by hand, threshed and weighed to have an indication of total yield. This was only done at ten fields to cross check existing data on yields.

Ninety water users were selected in three tertiary blocks to conduct standard questionnaires. Thirty water users were selected in a stratified sample from the list of water users in a tertiary block. The stratification was done on location of field in the area (head-middle-tail), land holding and male/female registration. All ninety water users were interviewed twice: once at the beginning of the 98-99 irrigation season and once at the ending of that season. Questions were asked on agricultural practices, crop production, opinion on the irrigation service, and participation in the WUA.

1.7.4 The water flow measurement program

The assessment of the performance of actual water delivery in a large-scale irrigation system is a difficult undertaking. Important difficulties encountered were: unsteady flow; differences in practices during day and night-time; the sheer number, length and variation in canals; hostile operators who fear you are interfering with and monitoring their job; hostile engineers and operators who fear their actual practices or lack of control are revealed.

Still it is extremely important to try to assess somehow the way in which water is distributed in practice (Murray-Rust and Snellen 1993). Any evaluation of the functioning of an irrigation system, without an idea of how much water really is delivered to certain areas, can only have partial conclusions.

In the measurement program two issues are important: first the execution of the measurement itself, and second the design of the program of various measurements in space (number and position of control points along the canal network) and time (number of repetitions and period of evaluation).

When looking at the individual measurement we have to consider the reliability, validity and precision of the measurement. Reliability has to do with the stability of the measurements outcomes: two measurements at the same control point within a relative small time period would have to give more or less the same outcome. Reliability has to do with the measurement instrument (are all parts functioning well?), the person who does the measurement (does the person know how to execute the measurement and was the measurement actually performed well?), and the water flow itself (is the flow stable enough to do a meaningful measurement?). In any extensive measurement programs errors are made in execution and calculations. If a certain outcome is outside the range normally expected this outcome could be left out of the data set. It is important to crosscheck the data. For example if measurements are taken at different levels in the canal system at the same day, data at higher and lower levels can give indications of the possible range of the flow in-between.

Validity has to do with the appropriateness of the measurement. It is the degree to which you are measuring what you intend to measure. We did measurements at field intake level. This caused challenges. For example, when a certain flow is perceived to be the only flow going to the field, while in reality a little further upstream a part of the flow is diverted to another part of the field. Also one might encounter an illegal water intake. If it is perceived as an official turn, and the flow is not the official 160 l/s, this distorts our evaluation of the performance of the official water distribution. Validity of the measurements has much to do with the objective of the measurements: see next part on the design of the flow measurement program.

The precision of the water measurement depends on the instrument and method used. We used a 'pigmy' Ott current meter with three different propellers. The current meter was calibrated during the research period in the Laboratorio Nacional de Hidraulica in Lima. We took about seven to ten sections across the canal and measured at 60% of the water depth. We measured 30 seconds in each section. The level of error of this method is somewhere between 10 and 30%. As we had only one current meter and sometimes had to measure water flows at more than one place at the same time, we also used in some cases a float (plastic bottle almost full with water) to estimate the velocity of the water. In those cases we used the average of about four velocity estimations over a canal length of 20 metres. To our surprise the float velocity multiplied by a coefficient of 0.80 or 0.90, depending on the depth of the canal, gave outcomes very close to the outcomes of the measurements with the current meter.

The design of the measurement program in space and time depends on the objectives of the measurement program. A measurement program is a way to evaluate the distribution of irrigation water in the irrigation system. In an evaluation always two sets of data are compared: one is the measured data and the other is the data regarded as optimal. In irrigation delivery performance mainly two criteria are used (Bos *et al.* 1994, Merrey 1997):

RWS = Relative Water Supply, this is the ratio of the water supplied to the water demand in a specific command area, given specific crops and cultural practices. This gives an indication of the technical efficiency of the water supply: what part of the water entering the system is used by the crops? (see also Keller 1986)

DPR = Delivery Performance Ratio, this is the ratio of water supplied to water programmed to be supplied. This gives an indication of the effectiveness of the technology and its operation: can the flows be regulated according the plan?

The indicators are commonly used only at the level of the main and secondary canals, but in this research is was also relevant to monitor the distribution at tertiary and field level. In this research mainly the DPR was used, because in rice farming the crop water requirements are hard to estimate, because they depend much on the infiltration rate, which was unknown. The water flows at all points in the canal system are planned according to the on-request schedule and thus could be compared to the actual flows. This gives a better indication of the

performance of the delivery than using the RWS, which in fact assesses the combined effect of both the allocation and delivery.
Then, to make an evaluation of the performance of the delivery, key control points at three different levels in the system were selected in the case study areas in Chancay-Lambayeque. In Jequetepeque only some flow measurements were taken at level of the intakes of the tertiary blocks. Table 1.3 presents an overview of the levels, methods and goals. In the Lambayeque and Muy Finca secondary canals, the intake was compared with the programmed intake. In Lambayeque the personnel of the *Comisión de Regantes* measure the intake of the three secondary canals every morning with a current meter. These data were obtained for the period 1 February – 22 April 1999. In Muy Finca two Parshall flumes are used to measure the intake in the secondary canals. The dimensions of the flumes were checked (and found correct) and the data was copied for the period 2 – 13 January 2000.

In Chancay-Lambayeque two pairs of students measured the intake of two tertiary blocks each morning during a period of six months during the 1998-1999 irrigation season. Each pair would follow the water inside the tertiary block to see where it was being used. If they were lucky they only needed to bicycle to one farm intake and measure the water there to know the actual flow delivered to the farmer, and the volume of water lost by percolation in the tertiary canal. On unlucky days the water was split up inside the tertiary unit and up to six farmers would be irrigating at the same time. This would mean much more bicycling and measuring. When driving and walking along the canals the students also observed and registered any water stealing or leakage from the canal in drains or fields.

Table 1.3: Levels, methods and goals of water measurements in Chancay-Lambayeque

Level	How measured	Goal
Intake from main canal to secondary canal	Data taken from *Comisión de Regantes*, they use Parshall flumes (register every 2 hours) or current meter (measure twice a day)	Assess performance of the main canal operation
Intake by tertiary block	Own measurements with current meter or float (4 students)	Assess performance of the secondary canal operation
Delivery to individual field	Own measurements with current meter or float (4 students)	Check losses and thievery along the tertiary canal

The water measurements inside the tertiary units provided much useful information, both on actual flows delivered to the water users, and also on the compliance of the on-request water turn schedule. The students registered the owners of the plots that were receiving water. These names were later compared with the official schedule. In this way water thievery, exchange of water turns, and illegal water selling could be detected.

As water flow was measured at the intake of the tertiary block and at all delivery points (fields) the percolation losses in the tertiary canals could be calculated. These calculations also clearly showed the problems encountered when measuring water in a system with much regulation, and thus unsteady flow. From the water loss calculations sometimes it seemed as if water was not lost but gained: more water was delivered than taken in. This can be explained, partly by the errors in the measurements, but much more by the unsteady flow. Sometimes, we were measuring the flow entering the tertiary block during an increase of the flow and some time later would measure the field deliveries when the water intake in the meantime had increased considerable. Then we would find that more water had been delivered in total to the fields than we had measured to be taken in. The other way around could also happen, resulting in perceived (calculated) high losses in the tertiary canal. The only way to account for this difficulty was to use the average of over a hundred measurements at both intake and fields.

1.7.5 Obtaining official documents and records, and archive research

Both for the qualitative study on the management as for the qualitative assessment of the water delivery official records, minutes of meetings and other documents were obtained. Print outs of the registers of official right holders, and their irrigated areas with the crop officially allowed to grow were obtained from the automated *padron de usuarios*. Also official regulations, documents on financial management -especially the water fee payments - were requested from the *Comisiones* and *Juntas*. Data on water measurements, scheduling and river discharges, were also obtained from the *Comisiones, Juntas* and local office of the Ministry of Agriculture (ATDR).

Literature research was done both at Wageningen University, The National Library in Lima as in the local public library, the libraries of the NGOs IMAR Costa Norte and Solidaridad in Chiclayo, and the Universidad Pedro Ruiz Gallo in Lambayeque. Relevant articles from local and national newspapers were collected. Many interesting documents on water rights and water related conflicts from the period 1600- 1800 can be found in the archives of the Archivo Nacional de Peru (situated on the ground floor of the building of the *Palacio de Justicia* in Lima).

1.7.6 Some limitations

As the research is focused on a wide range of aspects within the two case study irrigation systems, the study has some clear limitations on the profundity of the inquiries. Both flow measurements and field observations cover only a small sample in time and space. The two irrigation seasons were relatively wet. This, of course, influences the outcomes of the investigation. Large-scale irrigation systems are complex units. Events in any irrigation system follow up fast, and as soon as you start to understand a certain aspect, a large number of new questions come up and very quickly new events change the situation you were starting to comprehend. Doing research in two systems, and in different locations within these systems, at the same time, means that you cannot always follow up on events. This made the research more 'explorative' than 'deep anthropological' or 'hard technical'.

Conducting flow measurement only during daytime and always showing up on the same spots at the same time every day, is certain to have influenced the outcomes. Three times a visit was paid to the tertiary units at night, to observe whether the water levels drop at night, as some farmers told me. This could not be observed. However, it would have been interesting to have a 24-hour registration of the water flow at some points in the canals. The influence of our measurement program on the operation strategies of the *sectoristas, tomeros* and *repartidores* is hard to assess. As soon as the staff of *Comisiones de Regantes* and *Comité de Canal* realised what we were doing, they must have changed their 'illegal practices'. So if we registered a ten percent of illegal water turns this must be on the safe side in comparison with the non-observed situation. One can also expect that the tertiary blocks where we measured got more than their usual supply of water to show the good functioning of the system. However, it could equally be suspected that supply was kept below normal to show the problems in water provision to be able to provide 'hard evidence' while staking a claim for more compensation of percolation losses. As the research focused on all factors influencing the allocation and delivery of water to the tertiary blocks, the presence of the researchers had to be accounted for as one of these factors. The effect of our measurement program was assessed by asking the water users in the tertiary block if they noticed any change in the provision of water to their block. Only one farmer once told me he thought water delivery service was worse since we started measuring, but other water users did not confirm this.

1.8 Outline of the thesis

In this first chapter the topic of volumetric water control, its relevance for the North Coast of Peru, the analytical framework to study it and the methodology employed were outlined. Chapters 2 and 3 start the exploration of the operational realities of volumetric water control. Chapter 2 introduces the climate conditions and the rich history of irrigation along the North Coast. It shows historical continuities and discontinuities in technology, institutions of water management and problems faced in system operation and management. It also describes the present agricultural production systems. Chapter 3 begins the field study with an overview of the realities of the contemporary water management entity that comprises different levels of water users' associations and different governmental agencies. It describes the physical layout of the two irrigation systems, the water and land use and the organisational design. The description uses cases of conflict to highlight some of the domains and power relations present.

Chapters 4 to 6 continue the results from the field study emphasising the different dimensions of volumetric water control: allocation, delivery and charging. Chapter 4 focuses on the water allocation in both systems. It describes the national water laws and how it is used. The actual water allocation and scheduling are depicted. Chapter 5 first presents a framework for understanding water delivery performance. It then pictures the actual distribution of the water in both systems. In Chapter 6 the financing of the operation and maintenance is discussed. The setting of the fee, the fee recovery and the actual spending of the money are subject of scrutiny here.

Chapter 7 investigates volumetric water control in relation with productivity and equity. It links the diverse findings in the light of the three dimensions to analyse the dependence and interrelations between the divers aspects of volumetric water control, its successes and failures.

The conclusions are summarised in Chapter 8. This chapter is concluded with an 'epilogue' reflecting on the analytical framework and the research methodologies used, and finally makes some recommendations for intervention practices and further study.

2. Natural resources, history of irrigation, and production systems in the North Coast

2.1 Introduction

This chapter will set the scene for the detailed analyses of volumetric water control in Chapters 3 to 7. The chapter will provide the reader with information on the history and context of the organisation of the contemporary irrigation systems in the North Coast. First, the natural resources will be briefly described: the layout of the watersheds, the climate and soils. Second, the long and intriguing history of irrigated agriculture in the North Coast will be presented. The continuity and change in the governance and management of the irrigation systems are most relevant in the light of the understanding of the present organisation and performance. Different historical epochs can be distinguished by the specific relations between the State, the local elite and the governance of the irrigation systems. The historic developments will show that the idea of volumetric water control is not new. From viceroy Toledo in 1577, to president Leguía in 1910, to the water law from 1969; increasingly the idea of volumetric allocation, delivery and charging was promoted. Finally, the chapter concludes with a description of five different production systems found in Chancay-Lambayeque and Jequetepeque irrigation systems and the role of agribusiness in irrigated agriculture.

2.2 Natural resources in the two watersheds

Topography and land use of the watersheds

The Chancay-Lambayeque irrigation system has a command area of about 110,000 hectares and is situated in the lower part of the Chancay-Lambayeque watershed. The watershed has a surface of 6,166 km^2. It consists of two clearly separated parts: the upper catchment (3644 km^2, with about 100,000 inhabitants) and the coastal plain (2522 km^2, with about 740,000 inhabitants). The upper catchment is situated in the Cajamarca department and the coastal part is situated in the department of Lambayeque. The coastal valley floors are roughly triangular in shape. At the point where the river breaks out from the narrow valley neck the river moves at a reduced grade across the alluvial fan. The city of Chiclayo with about half a million inhabitants is situated in the coastal plain. Key economic sectors in Chiclayo are trade, transport and other services. Industry is limited to the sugar refineries and related soft drinks factories, the Nestlé complex and a limited number of smaller factories. In the irrigation system sugarcane, rice, maize and beans are grown.

The Coastal plain is a desert. Only the irrigated parts are cultivated. Natural vegetation ranges from none (sand dunes) near the shore to dry forest (with algarrobo) near the food hills. The algarrobo forests have been cut for the most part for firewood.

The upper catchment ranges from 500 to 3,500 metres above sea level. It is a poor and remote area and the road connecting the upper catchment with the lower part is in very bad shape. The upper valley is intensively cultivated, including the steep slopes, with maize, potatoes, beans, cassava, wheat and other 'Sierra crops' (40%). Natural grasslands form an important part of the land use (12%), and dairy forms an important economic activity. Annual precipitation is between 300 and 1,000 mm/year. Natural vegetation is subtropical cloud forest (20%). Some of the agricultural land is irrigated, but water use does not affect the water availability of the irrigation system in the coast. In most parts the cloud forest has been replaced with grassland and cultivated land. Soil erosion is an increasing problem: in 1994 about 50,000 ha were affected by erosion in the upper part of the watershed. Except for some mining activities agriculture is the main economic sector in the upper catchment (IMAR 1997a). Young men migrate to the coast for seasonal work in rice cultivation (Garcés and Guerra 1999).

The Jequetepeque irrigation system (41,000 ha) is situated in the lower part of the Jequetepeque watershed. The coastal plain of the Jequetepeque rivershed is part of the department of La Libertad. Some 140,000 inhabitants live mainly in the small towns like Chepén (40,000 inhabitants), and some smaller settlements like Pacasmayo, Guadalupe and San Pedro de Lloc. Main crop in the Jequetepeque irrigation system is rice. Maize is grown as a second crop. The only industry is the large cement factory in Pacasmayo. No crops can grow without irrigation in the coastal plain. The upper and lower parts are connected by a good access road. (CESDER 1995)

The Jequetepeque watershed is somewhat smaller: 5136 km^2, of which twenty percent is cultivated. The slopes in the upper catchment (4136 km^2) are steeper and the vegetation even more sparse in comparison with the Chancay-Lambayeque watershed. In the upper valley, 17 percent of the area is cultivated with the same type of crops as in the upper part of the Chancay-Lambayeque watershed. The upper part is situated in the department of Cajamarca and has the same sort of climate as Chancay-Lambayeque. The about 115,000 inhabitants live in small villages.

Climate

The climate in the North Coast is influenced by the Humboldt and El Niño currents in the Pacific Ocean. If it were not for the rivers bringing water from the Andean Mountains the complete Coast would be a desert. Precipitation is practically zero in normal years, except for dew formed on obstacles due to the humid air blowing from the sea. Once in about fifteen years the El Niño current moves further south than normal and causes a temporarily climate change. In the North Coast the El Niño phenomenon brings periodic torrential rainfall in the beginning of the year[1]. Floods have been reported from the early colonial times onwards. Hocquenghem (1998) made an overview of all reported El Niño floods in Peru. During the last two centuries the following years registered disastrous floods in the North Coast: 1821, 1828, 1871, 1877, 1884, and in 1900, 1914, 1925, 1953, 1957, 1971, 1983 and 1998.

[1] The study period started in 1998 in the aftermath of one of the strongest El Niño events of the past centuries. Some parts of the irrigation systems were heavily affected. In Chancay-Lambayeque the main canal was partly damaged and many aqueducts crossing drains were destroyed. In Jequetepeque much agricultural land along the Jequetepeque river was washed away. Also here one of the main canals was damaged. With help of World Bank loans many of the destroyed works were reconstructed during the 1998-2000 period.

Although there is almost no precipitation in normal years, the relative air humidity is high: in daytime around 60 to 70 percent and at night up to 100 percent. This air humidity comes from winds blowing from the ocean. The cloudiness is low. Almost all days there is full sunshine. This gives a high production potential to tropical crops. Temperatures are quite stable. In what is called 'summer', from December to May, the average maximum temperatures are around 28 degrees with warm nights. In what is called 'winter', from June to November, the average maximum temperatures are around 23 degrees. Night temperatures can drop below 15 degrees, but usually stay around 16 or 17 degrees. Table 2.1 gives more details on the climate in Chancay-Lambayeque. The average data for Jequetepeque do not differ much: temperatures tend to be a little higher in summer and a little lower in winter compared with Chancay-Lambayeque. However, temperatures vary in the irrigation systems depending on the location. Closer to the ocean the temperatures are a couple of degrees lower. Wind direction is almost always inland, and wind speeds are low to moderate.

Table 2.1: Climate averages Chancay-Lambayeque (Climate station Lambayeque, 1987-1996)

	Temperature (°C)	Minimum temperature (°C)	Maximum Temperature (°C)	Precipi-tation (mm/month)	Relative humidity (%)	Sunshine hours (hours/day)	Eto (PenMon) (mm/day)
Jan	24.3	20.6	27.9	3	72.5	8.7	4.6
Feb	25.8	22.2	29.4	3	71.3	7.8	4.8
Mar	25.5	21.7	29.3	14	71.1	8.5	5.1
Apr	23.9	20.3	27.5	6	73.3	8.1	4.8
May	22.3	19.0	25.7	2	75.2	8.2	4.3
Jun	20.6	17.5	23.6	4	77.3	7.9	3.8
Jul	19.5	16.5	22.3	2	78.1	8.1	3.7
Aug	19.2	16.2	22.2	3	78.6	8.3	3.8
Sep	18.4	16.3	22.5	5	77.9	8.2	3.9
Oct	20.0	16.7	23.3	2	77.2	8.6	4.1
Nov	20.6	17.2	24.3	2	75.2	8.4	4.1
Dec	22.2	18.6	25.7	2	75.3	8.8	4.0
Mean	21.9	18.6	25.3	-	75.3	8.3	-
Total	-	-	-	48	-	-	1,553

River discharges

Water for irrigation in the North Coast, in the normal years (years without El Niño), comes from highly fluctuating and unpredictable rivers that flow from the Andes, fed by the rains falling in the hills of the West side of the Andes. There are no snow peaks in this part of the mountain range. Rains fall mostly between January and May. As the catchments are relatively small, and the slopes steep and often sparsely vegetated, the concentration time is only a few days. Farmers in the Coast look at the sky above the mountains in the East to judge whether or not rains will fill the river soon. Government officials use the ocean temperatures to predict rainfall and therewith river flows in the coming irrigation season. However, as De Bruijn (1999) has shown: the river flows are completely unpredictable beyond a few days.

The average annual discharge of the Chancay river for the last forty years is 985 million cubic metres per year. However, this includes also the El Niño years in which rainfall is much more than in normal years. The lowest volume in the Chancay river registered last forty years was 375 million cubic metres in the period 1979-1980. The highest volume registered was during the El Niño of 1998: 2,122 million cubic metres. The 75% chance of exceedance was 689 million cubic metres per year (De Bruin *ibid.*). Average discharges of the Jequetepeque river the past sixty years, including the 'El Niño discharges', is about 841 million cubic metres per year. Lowest discharge of the Jequetepeque river was in 1979/80, when only 88 million cubic metres passed the measuring station. The El Niño year of 1998 brought 2,629 million cubic metres to the valley. This shows the flow variability with which the irrigation schemes had to deal. The 75% chance of exceedance was 442 million cubic metres per year. Detailed information can be found in Appendix II.

The river discharges not only fluctuate over years, but also between weeks and even days. In Figure 2.1 the graphs of the monthly discharges show clearly the wide variations of discharges over month and years.

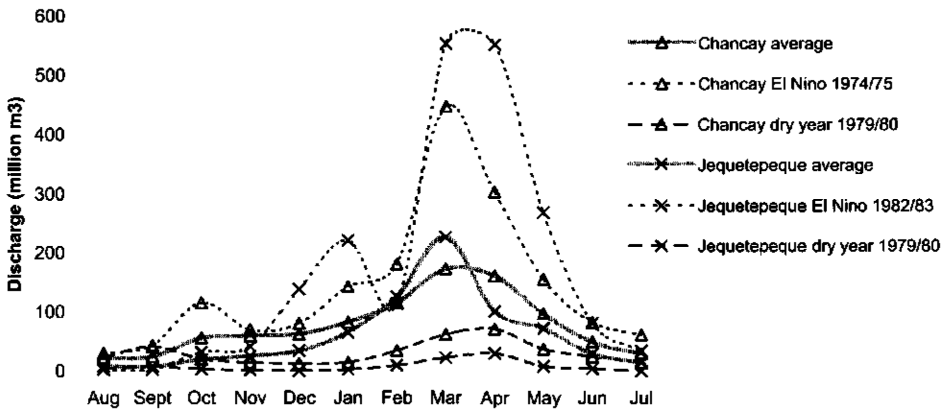

Figure 2.1: River discharges of the Chancay and Jequetepeque rivers (Sources: IMAR 1997b, Carpio and Mejia 1996)

Soils

Both irrigation systems are situated in alluvial fans. The riverine deposits have created a mix of heavy, medium and light textured soils. The higher river terraces near the foothills are more sandy. Due to the high temperatures, the organic matter content is low. The ground water table is between one and three metres below the surface. In the lower rice growing areas waterlogging occurs during the irrigation season. There is very little soil-profile development. Where the water table is less than a metre below the surface gley-soils are developed at a depth depending on the minimum water table. Due to lack of drainage, the salinity of the irrigated soils in both Chancay-Lambayeque and Jequetepeque has increased considerably in the last couple of decades (see section 3.3.3).

Ground water use

Remarkably little ground water is used. Until recently the local irrigation office (ATDR) required the growers of sugarcane to possess a tubewell. This was because the irrigation systems could not be held responsible for delivery of sufficient water in the dry season. The sugarcane growers, however were not obliged to pump ground water, it was only for emergency in water scarce periods. In most years, the sugarcane growers hardly used the pump, because they could secure sufficient water due to their position in the head-end of the Chancay-Lambayeque irrigation system. In recent years, all pumps have been removed from the tubewell sites. Pumping irrigation water is simply too expensive. Ground water is used in the tail-end of the system, near the Chancay river, in the *Comisiones de Regantes* of Monsefú, Reque and Eten. It is used to grow vegetables and alfalfa.

2.3 History of irrigation and water rights in the North Coast of Peru

2.3.1 The irrigation systems of the Moche, Sicán, Chimú and Inca

The history of irrigation in the North Coast of Peru goes back more than three thousand years. As the coast is extremely arid, agriculture was only possible with some form of irrigation. First settlers survived from gathering and hunting and later turned to sea-fishing. Around 1400 BC irrigated agriculture started to develop and gradually replaced fishery to become the prime food producing activity in the coastal areas (Moseley 1974). Remains of ancient irrigation works and canals still can be seen in the desert land surrounding the present irrigation systems of Chancay-Lambayeque and Jequetepeque (see Figure 2.2). However, because most of the ancient irrigation canals are still in use today they are hard to identify and date. Table 2.2 provides an overview of the epochs in the pre-Hispanic history of the North Coast.

Table 2.2: Pre-Hispanic cultures in the North Coast (Source: Sandweiss 1995)

Periods in North Coast of Peru	Period	Remarkable archaeological sites in the Lambayeque department
first settlements	9500 BC	-
Initial Period	1850 – 900 BC	first (flood) irrigation and pottery
Chavín (Sechin)	900 - 200 BC	Batán Grande (pottery), Purulén, small canals
Moche	200 BC – AD 600	Lord of Sipán (jewellery, pottery)
Late Moche/ Early Sicán	600 – 1050	Pampa Grande (city of 10,000 inh.), Apurlec (irrigation work)
Sícan (Lambayeque)	1050 – 1350	Túcume (pyramids), Batán Grande (gold), Taymi canal
Chimú	1300 – 1470	- (expanded from Chan Chancay-Lambayeque, Trujillo)
Inca	1470 – 1532	- (expanded from Cusco)
Spanish conquest	1532	-

Most probably the Chavín and Moche used a sort of spate irrigation, where they used the peak discharges of the Jequetepeque and Chancay-Lambayeque river to grow crops like beans that could survive on just the humidity created by the flood. They also used sunken gardens and small canals to irrigate crops.

Large-scale irrigation developed in the late Moche and early Sicán (or 'Lambayeque') periods from AD 600 onwards. These irrigation systems had three important characteristics: (1) They were large-scale systems, with command areas larger than the present irrigation systems. (2) Canals interconnected coastal valleys. (3)The management of the systems was in hands of powerful political-religious elites.

The command areas around AD 1,100 surpassed or equated the command areas of the contemporary irrigation systems: *"Archaeological research has shown that the valleys occupied by the Moche had a high density of people, supported by crops watered by their ingenious canal system. In the Jequetepeque Valley, Herbert Eling of the University of Texas, at Austin recently concluded that the Moche cultivated about 100,000 acres (40.000 ha) - a figure surpassed by modern Peruvian farmers only in the past 20 years."* (Donnan 1990:26) In Jequetepeque in the Chimú period (AD 1300-1470) this area increased to 77,000 ha (Eling

1978), against a maximum of 45,000 ha at present. Almost all present canals were already in use in the Chimú period. In Chancay-Lambayeque the estimated command area was 96,700 ha against 110,000 ha at present (Kosok 1958).

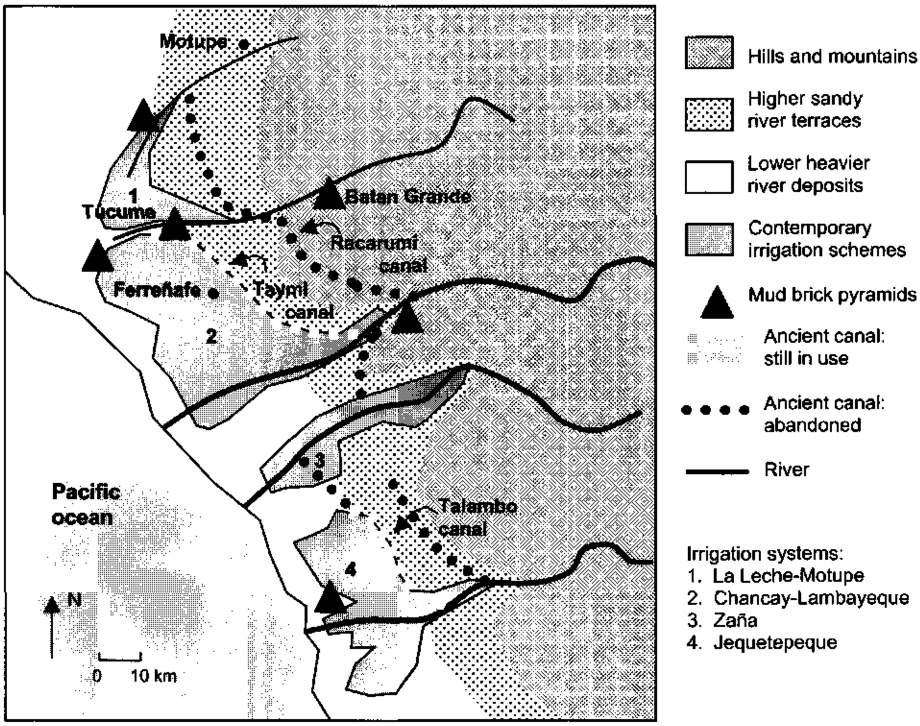

Figure 2.2: Map of contemporary irrigation schemes, abandoned canals and most important mud brick pyramids (Kosok 1965 and own data)

The irrigation systems built by the Sicán were large-scale systems with intakes from the main rivers, large main canals, and a hierarchical network of smaller canals to distribute the water. The water level in the rivers was raised and the water guided in to the canal intakes by means of stone and brush weirs, which were built out into the river at an angle. It is assumed that water was distributed proportionally among the secondary canals and rotated among the plots; a distribution system known as '*mita*' (explained in section 2.3.4).

The crops grown then were less water demanding than the contemporary rice and sugarcane. This partly explains why the Sicán systems could be larger than the present systems with reservoirs, permanent intake structures in the rivers and lined main canals. The available water could be spread more 'thinly'. A wide variety of vegetable and fruit species was cultivated[2]. Also cotton was grown. Animal protein came principally from llamas, guinea pigs, fish and edible iguanas.

[2] Vegetables: maize (*Zea Mays*), beans (*Phaseolus vulgaris*), gourd and squash (*Cucurbita moschata/Lageneeria sicereria*), avocados (*Persea americana*), chilli peppers (*Capsicum* sp.), peanut (*Arachis hypogea*), casava

Irrigation in the valleys was first developed on the higher river terraces, close to the hills. These were the more sandy soils, which drain naturally and do not need drainage systems to prevent salinisation. The more heavy soils in the lower parts of the valleys were prone to salinisation and had dense natural vegetation that was harder to clear (Farrington 1974). The present systems are more concentrated on these lower terraces. Therefore, most ancient canals, still visible in the desert, are found in the foothills of the valleys. For example, the 50 km long Racarumi canal from the Sicán period in Chancay-Lambayeque, and several canals in the 'Pampa de Cerro Colorado' area north of the Jequetepeque irrigation system. (see Figure 2.2)

Large canals interconnected different valleys along the Coast. The Talambo canal brought water from the Jequetepeque river to the Zaña river (some 50 km north). The Taymi and Racarumi canals, first constructed between AD 1000 and 1100 (Sandweiss 1995), brought water from the Chancay river to the La Leche valley some 60 km north. Canals took La Leche river water even further north to the Motupe valley (40 km) (Kosok 1965). Ortloff (1988), Kus (1984), Zegarra (1978) and Farrington (1978) describe the challenges of construction and hydraulics of these large canals.

The development of the large-scale irrigation seemed to have gone hand in hand with development of a strong hierarchical political structure, in which the local political and religious elite had absolute domination over irrigated production. Archaeological evidence shows that the Moche, Sicán and Chimú were highly developed civilisations with a strong political stratification and craft-specialisations: especially metallurgy, ceramics and weaving[3]. The cultures can be characterised as 'hydraulic societies' as defined by Wittfogel (1957). There was a despotic leadership, which had the power and ability to co-ordinate and enforce the mass labour needed for construction and maintenance of the irrigation works, irrigation water allocation and distribution, and the co-ordination of the irrigated agriculture in general. The elite accumulated the surplus generated by the irrigated agriculture (Netherly 1987).

Apart from irrigation, other features of the Moche, Sicán and Chimú culture tell about their 'glorious past': the mud-brick pyramids still found at numerous places in the valleys of the North Coast. "*The hierarchy of power and authority necessary for such a [irrigation] system also would have been required for the construction and maintenance of the massive mud-brick pyramids. The Pyramid of the Sun contains more than 140 million mud bricks, estimated to weigh more than four million tons*" (Donnan 1990:26) Kosok (1965) has done an extensive study on the mud-brick pyramids and their location in the Chancay-Lambayeque valley. He found fifty archaeological sites related to Moche, Sicán and Chimú culture, many of them related with the position of canals. The most important is the Túcume temple complex situated at the end of the Taymi canal (see Figure 2.2).

(*Manihot esculenta*), potato (*Solanum tuberosum*) and sweat potato (*Ipomoea batatas*). Fruits: *guayaba (Psidium guajava)*, pacae (*Inga edulis*), *olluchu, pepino (Solanum muricatum), chirimoya (Annona cherimola), guanabana (Annona muricata), lúcuma (Pouteria obovata), algarrobo (Prosopis pallida),* (Donnan 1990, Alva 1994, Sandweiss 1995, Hocquenghem 1998 and Kus n.d.).

[3] The rulers of the Moche, Sicán and Chimú combined political and religious leadership. We know much about the Moche leaders because several untouched tombs of Moche leaders have been found. The most famous is the grave of the 'Lord of Sipán'. The amounts of high quality and sophisticated gold and silver jewellery, and high quality pottery and cloth indicate a rich culture with highly specialised craftsmen and surplus food production enabling many persons to work in the jewellery and pottery production.

Besides the graves and mud-brick pyramids, also the sophisticated pottery (especially of the Moche) tells much about their culture. Several museums in Peru are packed with the fine ceramics of the Moche. Many are shaped as, or decorated with clay figures depicting, different animals, fruits, vegetables, shells, boats, buildings (temples), and especially people. The Sicán culture was especially good in metallurgy. Amazing amounts of gold and silver jewellery were found in Batán Grande. Much of the gold exhibited in museums in Peru and elsewhere, presented as 'Inca Gold Treasures', comes from the Sicán burial sites in Batán Grande. These again demonstrate the success of the 'hydraulic societies' in producing food surplus for craftsmen.

Archaeological evidence suggests new elements were added to the cultural expressions of the people in the North Coast with the conquering of the coastal people by cultures from other places: the Chimú from Chan Chan (Trujillo) around AD 1300 and the Inca from their highland empire with its capital Cusco in 1470. However, no abrupt changes were noted (Sandweiss and Narváez 1995). The Incas simply imposed their rule on top of the existing hierarchy, without changing the existing political structure. This was symbolised by building Inca temple elements on top of the existing Chimú pyramids. The elite position of the Inca rules was also expressed in the irrigation systems. The head-end parts of the irrigation systems were allocated to the new Inca rulers (Nuñez 1995).

2.3.2 Spanish conquest and the Chancay-Lambayeque irrigation system up to 1640

In 1532 Francisco Pizarro and about 160 *conquistadores* invaded the North Coast of Peru. They came for gold and other easy to steal treasures, but found mainly thriving agricultural communities. The divided Inca empire was easy to conquer (Prescott and Kirk 1887, and the chronicles of Cieza de León, Pedro Pizarro, Guaman Poma de Ayala, and Garcilaso de la Vega). The Spanish Crown established *'repartimientos de indios'*, congruent with present-day departments, which were divided into several '*encomiendas*'[4].

The *encomiendas* were granted to *conquistadores* as a reward for the services rendered. The idea was that the *encomenderos* would collect tributes from the Indios[5] and at the same time would convert them into Christianity. The Indios in the North Coast were to pay tribute in kind: cotton, food (maize), wool and some silver. The Indios could also be forced to provide labour (*mita*), especially in mining and construction of houses. The communities of native inhabitants were headed by *caciques*. A *cacique* was a man or woman with authority to rule the community. In most cases the position of *cacique* was inherited. The Spaniards used the *caciques* to control the native population.

The functioning of the agricultural societies could more or less continue, as under the reign of the Incas, to whom the coastal people also had to pay tribute. The Spanish king Carlos V ordered in 1536: "*The same system of water division used by the indios must be followed by Spaniards that are assigned land and the management of the irrigation systems must remain in the hands of the natives that held these posts before the conquest*" (Odar 1929:1151). See Figure 2.3 for a graphic presentation of irrigation at that time.

[4] It seems that in some documents the term '*repartimiento*' was used instead of *'encomienda'*.

[5] The term 'Indio' is used here because it was used by the Spaniards in the colonial times to refer to the indigenous people in the New World. It is more correct to speak of 'Indígenas' or 'original' or 'native habitants', but the negative connotation of the term 'Indio' felt by both the Spaniards and native inhabitants is functional in this part of the text.

Figure 2.3: Farmer irrigating in early colonial Peru, drawing by Felipe Guaman Poma de Ayala, living from 1587-1615

However, a dramatic disaster was to change life in the New World. The population was decimated by diseases brought from the Europe to which the indigenous people had no immunity. However, also the harsh exploitation in the silver and gold mines, and the brutal repression contributed to the death of millions of people. Hocquenghem (1998) gives data for Peru and for the North Coast. In 1525 about 15 million people were living in Peru. In 1571 this was reduced to a merely 1.5 million. In the Coastal areas of Peru the scale of the demographic collapse was even more dramatic. Only one out of each 16 people survived. In the Chancay-Lambayeque area the depopulation was less dramatic. Cook (1981) estimates that in 1575 about 38,000 people were living in Chancay-Lambayeque and in 1602 still 22,500: this makes him conclude that this is a special area were Indian agriculture remained important. In general the depopulation had tremendous effects on the agricultural society in the coast. Large parts of the irrigation systems could not be maintained and collapsed to be reclaimed only in the 20th century.

Although depopulation heavily disturbed the functioning of the irrigation systems, the systems remained in use, although many canals were abandoned. The German archaeologist Enrique Brüning found and published several documents in 1923 that describe the Chancay-Lambayeque system in the period from 1567 to 1610. This source of information is very special, not only for Peru, but even world-wide. It gives rare insights in the function of irrigation systems four hundred years ago, combining both Spanish and pre-Hispanic elements of irrigation water management. The documents reproduced by Brüning are:

1. *Ordenanzas* from Gonzales Cuenca drawn up in 1570 on request of the *cacique* of Ferreñafe.
2. Declaration of judge Diego de Arce from 1610: Order to enforce the Cuenca *Ordenanzes.*

The *Ordenanzas* of 1570 are from the hand of Gregorio Gonzáles Cuenca. He formed part of the colonial government in Lima and was *cidor* and *visitador general* for the city of Trujillo.

He was assigned by the Spanish crown to intervene in the management of the Taymi canal (now still the main canal of the Chancay-Lambayeque irrigation system) after conflicts arose in 1567 that could not be solved among the users of the canal. The new *Ordenanzas* resulting from the visit of Cuenca in 1567, became official State regulations in 1570 (and were signed in name of King Felipe II in Spain by the viceroy Francisco de Toledo in Lima).

The problem which called for the intervention by Cuenca in 1567 was the illegal construction of two new canals taking water from the Taymi canal (probably by original inhabitants that wanted to reclaim previously irrigated lands). The brother of the *cacique* of the tail-end *repartimiento* Ferreñafe complained in Trujillo about the opening up of the two canals. In the *Ordenanzas* of 1570 Cuenca mentioned that the *corregidor* of Trujillo, Hernanado de Saavedra, had earlier ordered to draw up regulations on the management of Taymi canal, on the basis of rules applied in Inca times. Saavedra had ordered the construction of fixed intakes of all secondary canals, and established penalties for those who would not do so and for those who would open up new offtakes. Cuenca noted that no intake structures had been built and no person was appointed to enforce the rules. In dry periods this had caused loss of crops for the Indios who cultivated land irrigated by the secondary canals in the tail-end.

In 1567 Cuenca asked elder Indios and Spaniards about which of the canals were in operation from the Inca times, and had the other offtakes closed. He also had the intakes of the twelve official secondary canals limited and demarcated with wooden logs to mark the original sizes from the Inca times. He also ordered permanent intake structures constructed of bricks and lime within three months. These intakes had to have a triangular shape with the basis at the floor of the canal[6] (except for the largest canal that had to have a square formed intake). The sizes were given in exact measures for all twelve intakes. The costs of construction were to be paid by the water users of the corresponding secondary canal. All water that was not taken by the twelve official intakes was to be used by the *repartimiento* Ferreñafe situated at the tail-end of the Taymi canal. In the case that no water reached Ferreñafe, the other intakes would have to be closed a little so as to allow a certain flow of water to Ferreñafe for domestic use.

The 1570 ordinances included the penalties for opening of new canals: 100 pesos for each time a Spaniard would open an unauthorised canal, for a *cacique* 25 pesos, and for an ordinary Indio 10 pesos and a public beating. Further, the costs of closing the canal and the losses suffered by the downstream users would be claimed from the person(s) opening the canal. It was also forbidden to close any of the official canals. The penalty of closing official canals was the payment of the crop losses.

Cuenca also drew up the rules for the maintenance of the main canal. Each group of water users was to clean once a year the part of the main canal between their intake and the next upstream intake. The last part; from the first upstream intake to the river, would have to be cleaned by all water users together. The maintenance of the secondary canals had to be done by the water users benefiting from these canals.

Further Cuenca asked for a water manager (*juez del Taymi, juez de aguas*) to be appointed to manage the Taymi canal. The salary was to be paid by the water users of the Taymi canal.

[6] From hydraulic point of view the triangular shape would cause a relatively stable flow in the offtaking canal. In times of water scarcity or abundance, the problem of lack of water or excess water would be felt mainly by the tail-end water users. This seems to have been the general principle of the water distribution. Both in Inca and colonial times the head-end users were explicitly privileged above the tail-end water users.

The *juez* was not to posses any land irrigated by the Taymi or Túcume canal and was to have no relations with any of the *caciques*. The penalty was payment of 1000 pesos to the *'cámara'* (court) and dismissal from the post. This, and other fines, were split up in three equal parts: one part for the *cámara*, one for the judge of the *cámara* and one for the accuser.

Forty years later the *Ordenanzas* of Cuenca seemed to have been at most partly effective. In 1610 the judge (*juez visitador general*) Diego de Arce had to order the construction of the same offtakes from the canals along the Taymi canal. Apparently they had not been built. Diego de Arce increased the penalties for non-compliance. If no intake structure had been built in two months the corresponding secondary canal would be closed, only to be opened upon building the required intake structure. Also the rules for cleaning of the canal seemed to have failed. Arce had to repeat the order of Cuenca on the way to clean the Taymi canal. This time Arce added penalties: no cleaning would mean no water.

The opening of new canals, or the altering or destruction of the structures to be built would be punished more severely in comparison with the *Ordenanzas* of Cuenca. For Spaniards: closing of a canal (Indios who would close an unauthorised canal of a Spaniard would not be punished), banishment for two years from the region, and 200 pesos to be paid to the local court and hospital for Indios. If the offender were *cacique*, the canal would be closed on his or her costs, the *cacique* would be banished from the region for two years, and (s)he would lose the position of *cacique*. If the offender was Indio, the first time (s)he would get 200 beatings in public, the second time the ears would be cut off. For all offences, the costs of closing the canal and compensation of losses by downstream users should be paid by the offender.

From the two documents we gain some important insights into the functioning of the Taymi canal from 1570 to 1610, but also in the period before that and even during the Inca times. First of all the management and resolution of conflicts focused only on the main canals and the offtakes to the secondary canals. The *caciques* had the task and authority to manage the land and water inside the secondary units, which most of the time coincided with the administrative unit called *'repartimiento'* in the documents. Second, the colonial rulers did not intervene much in the management of the system; they only sent a judge when one of the conflicting parties requested for such intervention. Third, the distribution of water was in fixed discharges of continuous flow to the secondary canals. The size (and shape: square or triangular) of the intake would determine the water to flow in each secondary canal. The water remaining[7] after the last authorised offtake was to be used by the *repartimiento* Ferreñafe that in times of low water flow would not have the right to irrigate, but got the *de jure* right to get water for domestic use. The mode of distribution of the water inside the secondary units is not mentioned. However, several chronicles (Cieza de Leon, Garcilaso de la Vega) indicate that water in pre-Hispanic times was rotated along the canals to irrigate each plot during a certain well-determined number of hours.

There has been a small debate among irrigation historians (Keith 1976, Netherly 1987, Glick 1996, Crouch 1996) as to whether the colonial irrigation in the New World was mainly influenced by the Spaniards, or that the Spaniards took over the existing systems without changing their operation. Netherly (1987) concludes that in both Andean and Spanish irrigation management both rotation and continuous supply was practised. Netherly states that a special feature of the Andean rotation was the rotation from tail to head-end, where the

[7] The idea of two classes of water rights: one with a permanent right, and a second with a water right only if the water rights of the first class are fulfilled, continues to the present day (see Chapter 4).

Spanish rotation always starts at the head-end[8]. Crouch (1996) emphasises the mix of Spanish and indigenous water management technology used by the Spanish settlers.

Keith (1976:122-123, emphasis added), however, states: "*... the techniques used for measuring water in the eighteenth century [in Peru date] from* 'the remotest times'. *These principles were* ***strikingly different*** *from those which governed the traditional Moslem irrigation systems found in southeastern Spain. While the [ancient] Peruvians created a bureaucracy to measure and regulate the flow of water by means of sluice gates (tomas), the Moslem built tongues of masonry to divide the water into proportional parts, making measurement unnecessary.*"

Glick (1996) stresses that two basic types of irrigation existed in Spain (related to different origin in the Muslim world): a system where water is bounded to the land (and water allocation is proportional to the size of the land), and the other type - mostly found in more water scarce areas - where water is not tied to the land and water turns can be sold. In both systems irrigation turns (*'dulas'*) existed which during water scarcity were determined in exact hours and minutes for each property. In Valencia the water was split up proportionally in flows called *'hilos'* or *'filos'*. Each canal was assigned a number of *'filos'*[9] (see also Maass and Anderson 1978). Glick explains how these systems were taken, first to the Canary Islands, and later to Texas by Spanish emigrants.

My conclusion from the historic documents on, and present functioning of, irrigation management in Spain and the North Coast of Peru are the following:

1. The Spanish *conquistadores* took over the physical and institutional system created by the Sicán, Chimú and the Inca: this included the assignment of fixed flows to main and secondary canals. The continued practices also included the specification of two different water rights: on the one hand a permanent water right for the head-end canals assigned to the high class (high class Chimú, later taken over by the Inca rulers, later taken over by the Spaniards), and on the other hand a right restricted to the use of excess water in the tail-end of the main canal.
2. Main differences between the Indigenous Peruvian system and the Spanish system were: (a) the assignment of fixed flows to canals in Peru, regardless of how and where the water is used; whereas in Spain water rights were bound to land, (b) the differentiation between permanent and excess water rights in Peru, whereas water rights were equal for all right holders in Spain.
3. Many features originally were found in both Spain and Peru before the conquest: (a) continuous flow to all canals in time of abundant water, (b) strict rotation among plots with defining turns in exact duration according to landholding in times of water scarcity.
4. From the 16th century onwards the Peruvian government tried to convert the water rights from assignment in fixed flows per canal to irrigated area. This already starts with the *Ordenanzas* of Toledo in 1577, and finally was implemented and practised with the Water Code in 1969.

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[8] This is counter to the finding of Glick (1995:30) who cites a finding of a Roman inscription indicating that rotation went both from head to tail and from tail to head.

[9] The expression of a water right of a canal in the number of the *'hilos'* comes quite close to the practice in Colonial Peru to assign users (and canals) a fixed number of *'riegos'*. However, the *hilo* is a proportion of the river, and the *riego* is a fixed flow. Nevertheless, the *riego* might have functioned in practice also like a proportion, because water flows could not be measured exactly (they were determined by a flow through an opening with a certain dimension) and the river flows fluctuated heavily.

2.3.3 The hacienda era

Although the two documents by Cuenca and Arce mention both Indios and Spaniards as possible offenders in the stealing of water, it must be concluded from the documents that most of the land was still in the hands of the native people[10]. Direct cultivation of land was not in the interest of the small Spanish population, because they received tribute from the natives. This was to change gradually during the 17th century. Spaniards become more interested in direct agricultural production as a means to sustain a living when the population of Spaniards increased and the tributes from the decimated native population declined. The first private land holding in the Chancay-Lambayeque irrigation system was registered in 1597. In the ensuing years more and more Spaniards had land registered on their name. Cattle ranches, *'estancias'* raised livestock (first sheep and goats, later beef cattle) and horses. Landholdings concentrating on cultivation of crops (first maize, later wheat and other crops) were called *'haciendas'*. Around 1640 sugarcane became more important. As with the *encomiendas* (administrative institution) also for the *haciendas* and *estancias* (private holdings) the native inhabitants had to provide labour: *Mitayo* and *Yanacona.*[11]

As more and more land was claimed by Spanish settlers, conflicts arose between the original land users and the newcomers. In the early 17th century, when cattle raising was the main activity of the Spaniards, the conflicts were about use of the communal grazing lands. However, by the later part of the 17th century the conflicts arose over land and water rights. As the number of Spanish landowners increased, the distribution of water needed to be regulated better. Customary rights were defined based on practices of water use. When disputes arose, customary rights to water were converted into property rights by means of decisions of judges. New Spanish settlers simply appropriated the best agricultural lands and sent away the original land users. Documents recording numerous court cases of Indios against *hacendados* are piled up in the archives under the Palacio de Justicia in Lima. Keith (1976) gives a lively account of the process of encroaching of Spanish *haciendas* to the disadvantage of the indigenous farmers in the valleys around Lima.

The Spanish Crown was not content with the violent and lawless treatment of the Indios, and drew up a number of regulations to provide some legal protection of the native people. One of the *Ordenanzas* viceroy Francisco de Toledo (viceroy of the Virreinato del Peru in Lima) drew up in 1577 was the regulation of water use in and around Lima (Lohmann 1989). Toledo drew up pretty much the same kind of regulations as Cuenca did in 1567 for Chancay-Lambayeque: fixed offtake structures, rules on canal cleaning, and no new canals. What Toledo added was that a piece of land should not take more than the water which was needed to grow a crop on it: *"Que se le dé a cada chácara por cuenta y razón el agua que hubiere menester."* (ibid:280). Toledo also ordered that the Spaniards would irrigate at day-time and the Indios at night-time. This last measure made it easier to safeguard the water flow for the native farmers. In later years (the first in 1617) judges regularly drew up regulations where the water from rivers is allocated in fixed discharges (expressed in number of *'riegos'*[12]) to

[10] In 1567 Cuenca mentioned Spaniards, but assigned all canals to *repartimientos* ruled by *caciques*. Arce in 1610 already mentioned canals that are owned (or used) by Spaniards. However, none of them mentioned *haciendas*, which later became so dominant in the conflicts on water.

[11] *Mitayo* is the system where native small landowners have to work for example 20 days per year on the neighbouring *hacienda*, this work is called *mita*. *Yanacona* is the system where landless natives live and work on the *hacienda* and cultivate a small plot with some subsistence crops.

[12] The *'riego'* in those days was expressed as the water flow through a square gate with certain measures. E.g. *"una quarta por una tercia of a vara"* (a *vara* is more or less one metre) in Trujillo and Lambayeque or *"una sesma quadrada"* in Lima (Ramirez 1974). Cerdán (1793) considered the *'riego'* to be a very ancient

each of the canals taking water from the river. These discharges were to be observed only in the water scarce periods. In water abundant situations the principle of *'toma libre'* applied. This means that upstream users have the right to take as much water as they like.

After a period in which Spanish settlers just took land, they turned to more 'lawful' ways of obtaining land. Keith (1976) mentions three ways: Indian lands were sold to Spaniards together with the water rights. Water rights were transferred by viceregal decree, because of continued decline of the Indian population they were regarded to no longer need the amounts of water they were entitled to. Finally, water rights were transferred by means of private agreements between Indians and Spaniards (for example to exchange part of their water for less, but more secure water supply).

By 1700 the distribution of land in Peru was pretty much established and was to remain more or less the same until the land reforms of 1969. The pattern in most irrigation systems along the coast was that some big commercial *haciendas* would occupy up to eighty percent of the irrigated land, always the best lands situated in the head-end of the irrigation systems. The remaining land was owned by either small (*mestizo*[13]) farmers and *comunidades campesinas* (the successors of the *repartimientos*). The *comunidades* had finely been pushed into a position that made agriculture almost impossible: they had land, but only right to excess water. The *haciendas* had priority right to the water. In fact two different water titles existed for the *haciendas*: one fixed flow assigned in all years (*'titulo de agua'*) and an extra flow assigned only when river flow was above normal (*'agua de excedente'*)[14]. Inside the *haciendas* and comunidades the allocation, distribution and water use was an internal affair. The *haciendas* appointed a *'mayordomo'* or *'caporal'* to manage the water on the estate. Undershot sliding gates were installed to allow for flexible water delivery inside the *hacienda*. Most *comunidades* had only right to excess water. They used a form of rotation of the water flow. Little is known to the author on how exactly the water allocation, scheduling and delivery was executed in the *haciendas* and *comunidades*. However, present water users confirmed the idea that the practices of rotation and field application used today have been in use since ancient times.

The *haciendas* in the North Coast concentrated on growing sugarcane for export. They had their own refineries (*trapishes*). Ramirez (1974) gives a vivid account of the boom and decline of the sugar *haciendas* in Lambayeque between 1670 and 1800. In Chancay-Lambayeque in 1700 there were six major sugar estates. The water allocation was in fixed discharges owned by the *haciendas*. Judges issued water titles to private landowners and communities along the principal canals in 1570, 1655 and 1700. After 1720, when forced labour by Indios was abolished, the *haciendas* became to depend on slaves from Africa and paid workers (both Indios and Mestizos).

The main argument of Ramirez is that the *haciendas* on the coast were intensively producing for the international market, had owners that actively managed their estates, and that the ownership did not remain in the hands of the same family, but changed hands due to

measurement that was used since the remotest times and that it was sometimes translated to an area to be irrigated with it.

[13] *Mestizos* are descendants from mixed *indigena* and Spanish origin.

[14] The allocation was sometimes also translated to areas to be irrigated, probably to make control easier. However in the regulations and documents on conflicts only reference is made to the size of the flows and the division structures to regulate them.

bankruptcies and other circumstances. The ownership of some eight *haciendas* changed from (former) State officials to Church (Jesuits) and merchants. The latter bought the estates after bankruptcy of the former during periods of low world market prices for sugar (e.g. in 1720), war with Chile (1879-83), or natural disasters like El Niño floods (e.g. in 1720 and 1728). After the sugar crises, other crops were introduced on the *haciendas*: tobacco and rice became commercial crops. To be replaced again with sugarcane in times of better sugar prices on the world market.

In 1856 Deán Saavedra drew up regulations for the Chancay-Lambayeque irrigation system. The regulations consolidated the existing order and legalised the new canals constructed by (large) landowners. In 1870 again new regulations were formulated, this time in a more participatory way. A commission with several local government officials and three farmers formulated regulations including: the exact amounts of water assigned to each title holder in times when water was scarce; and the confirmation of informal water rights (which were to be legalised as long as they did not interfere with the existing official water titles). Other lands that had no title and could not prove informal water rights were assigned excess water for grazing land (Odar 1929).

In Jequetepeque the *encomiendas* were taken over by the Order of Agustinos de Guadalupe in the 17th and 18th century. This religious order possessed all the *haciendas* in the valley and abused the labour of the Indios placed in *reducciones*. First mainly cattle was raised.

In 1821 Peru declared itself independent from Spain. With the Independence the domination of the Catholic Church in land holdings disappeared. Republican politics favoured secular landowners: the Augustin order in Jequetepeque had to give up its big landholding and the *haciendas* were allocated to military and other *criollo*[15] elite (Burga 1976). With the increase of more commercially oriented landowners, the introduction of paid labour accelerated. New capital from the selling of *guano* and construction of railways entered the valley and sugarcane returned as the main crop. All *haciendas*, but also most smallholders cultivated sugarcane. The sugar boom ended in the beginning of the 20th century and rice became the main crop.

From the second part of the 19th century until the land reform in 1969 the division between big and small landholdings remained quite stable. The *haciendas* (four large ones and several smaller ones) occupied about 40 percent of the land and the smallholders about 60 percent. The *haciendas* were situated in the head-end of the system and had the best access to irrigation water. The *comunidades indigenas* had no water rights and were situated at the end of the canals. Burga (1976:44) writes about the situation in 1904: "*There did not exist precise measurements, and they did not take the water velocity into account. The haciendas were undoubtedly the only ones profiting.*" As the *haciendas* took most of the water, many of the small landholders abandoned their lands, although they had official water titles.

2.3.4 Initial State interventions (1910-1968)

From the beginning of the 20th century to the land reform in 1969 the agricultural system became increasingly capitalistic. Labour relations became more regulated via the market, and *haciendas* operated as commercial enterprises. Entrepreneurs from outside the valley bought

[15] *Criollo* refers to descendants from Spanish settlers.

several large *haciendas*. Those new entrepreneurs in some cases owned more than one *hacienda*: one producing rice, another producing sugarcane and another in the mountains producing cattle. The most modern technologies were applied and productivity was high. The small and middle-sized landowners, and the peasants in the *Comunidades Campesinas* did not increase their productivity and suffered increasingly from lack of water.

Prior to the 20th century the Peruvian governments had intervened little in the management of the irrigation systems. During the colonial period the government had only reacted in case of conflicts and then sent a water judge to do some inspections, draw up some ordinances and legalise existing water distribution practices into water titles. During the Republican era the government had installed some institutions like an administrator chosen by the water users, and continued to employ some water judges. However, there was no interference with the daily operation inside the systems nor any contribution to the irrigation infrastructure. This was to change.

The start came with the formulation of the first national water law promulgated in 1902 in response to increased water scarcity, because of the increased population. This law was almost an exact copy of the 1879 Spanish *Código de Aguas*. The water code mainly consolidated the existing unequal distribution of water rights. The governance and management of the systems was to be executed by *Comunidades de Regantes*. The water users were to elect a *Sindicato de Regantes* (board of the *Comunidad de Regantes*) and an administrator. As the votes were according to size of the landholding, the big landowners controlled the position of the administrator and thus controlled the system as they did before (Valdez 1926). In Chancay-Lambayeque two *Comunidades de Regantes* were established: the three big *haciendas* in the 'Comunidad de las Haciendas' in the head-end and the 'Comunidad de Ferreñafe' organising the smallholders in the tail-end part of the system. In fact, the organisation of the water management changed little with the 1902 Water Code and left the governance with the local elite in the irrigation systems.

Real interference by the State started when president Leguía came to power in 1908. Leguía promoted State intervention to create an 'industrial revolution', and this included big irrigation works[16] and changing of the water allocation regulations. Several factors triggered the increased involvement of the national government in irrigation during the Leguía periods from 1908 to 1912 and 1919 to 1930. The international economic crisis of the 1920s decreased world market prices and exports collapsed. The population growth of *indigena* and *mestizos* increased the pressure on water and land resources, and water became increasingly a contested resource. The El Niño of 1925 destroyed many irrigation canals. However, principally there seemed to have been a change in ideology of the ruling class (in Lima), making the government change its '*laissez faire*' stance. The rich upper class, including state officials, became more aware of the immense poverty in which the lower class lived. They believed that technical modernisation to increase the productivity of agriculture, colonisation of new agricultural land, and government support of large irrigation infrastructure would be able to diminish the poverty, while at the same time maintaining the economic position of the *hacendados*. It was clearly not the idea to redistribute the big landholdings or give labour rights to day-labourers, but government was to come in to provide 'progress' to the country.

[16] Leguía constructed the El Imperial and started the Olmos and Majes projects and the foreign debts (mainly loans from the United States) were multiplied by ten during the Leguia administration (Urban 1990).

Engineer Valdez (1926:1005), subdirector of water affairs of the Ministry of Advancement thus explained the general idea of the need to State intervention in water management: "*No puede ofrecer mayor obstáculo para el desarrollo de la agricultura la permanencia de las reglamentaciones dades en épocas muy remotas, para satisfacer necisidades muy distintas de las actuales*". ("The remaining of regulations from very remote times, formulated to serve other interests than the contemporary ones, forms a major obstacle for the development of agriculture").

Starting from 1910 onwards, new laws increasingly diminished the power of the local elites and increased the influence of the national government. In 1910 the management of the irrigation systems came in hands of government appointed *'Comisiones Técnicas'* or *'Administraciones Técnicas'*. In each valley two or three engineers were assigned the post of administrator (Sutton 1929). In 1918 the Ley N° 2674 abolished the election of the *Sindicatos* and administrator, which in fact meant the take over of the control of the systems by the national government.

The new government officials started a whole program of 'technification' of the irrigation water allocation and distribution in the existing irrigation systems, aiming to increase the productivity of water. The idea behind this 'technification' can be summarised as 'volumetric water control'. The allocation of water was to be related only to a certain amount of land, and not, as was often the practice, proportional to a water title. The volumetric control necessitated the calculation of crop water requirements, establishing of the water layer to be applied in each irrigation turn and the number of water turns to be given each year to a certain crop, the measurement of river flows and the building of measurement and division structures in the canals. Also the idea of payment per volume of water applied was proposed.

In some valleys the new regulations ended the *'toma libre'* (right to take as much water as wanted) by the head-end *haciendas* (Valdez 1926). In other places division and measurement structures were built to implement a strict water distribution. In Chancay-Lambayeque the government officials formulated a new *Ordenanzas de Regadío de la Comunidad de regantes del Taymi* promulgated in 1928. The ordenances introduced many of the volumetric water control ideas of the government (Lizárraga 1929).

The ordinances introduce the idea of the '*módulo de riego*', which is a fixed volume of water to be applied to one hectare of a certain crop. This application was to be the same for large and small landowners. It was expressed in the number of water applications in a year. Each application being 600 cubic metres per hectare (the '*unidad de riego*'). The 600 m^3 were delivered at field level with a flow of 160 l/s, thus delivering the 600 m^3 in about one hour. The number of applications for a normal year was 15: thus allocating 9,000 m^3/ha per year, which could with maximum river flows become 15,000 m^3/ha. In times of water scarcity the water application per turn should still be 600 m^3/ha, but the irrigation interval would be longer: not each 10 days, but up to more than 100 days in times of low river discharges. The river discharges would be measured several times a day. Lizárraga (himself a government engineer, but not directly involved in the formulation of the ordinances) criticised the establishment of a maximum of 15,000 m^3/ha per year in the Chancay-Lambayeque system to be too much. He calculated the evapotranspiration and stressed the differences in water requirements for different crop types.

The new ordinances also established that water should be paid by volume applied, so as to give an incentive to save water, and appreciate its real value: "*se ha establecido que los derechos de regadio se paguen por volumen de agua recibida, en cuya forma todo agricultor sólo solicitará el agua que realmente necesita ; y esta será el único medio de consequir que aprenda a economizar el agua y darse cuenta del verdadero valor de ella*" (Lizárraga *ibid.*:738).

We do not know much on the actual application of these ordinances, but some new practices were enforced. As Tupac (1929) reports; with the stationing of soldiers at the division structures they were able to bring water to the tail-end of the canals. However, it is presumed that fairly little was changed, apart from the construction of the La Puntilla intake works and perhaps some measurement and division structures. However, the volumetric payment and the *módulos de riego* could most probably not be enforced.

Apart from the intervention in the allocation and distribution of water, the government also started the large Olmos project to increase the irrigated area by construction of reservoirs, canals and tunnels. President Leguía assigned Charles W. Sutton, an irrigation engineer from the United States, as chief of the National Irrigation Commission. He was to become the key man in promoting large irrigation infrastructure interventions by the State. Sutton is still renowned in Peru: a street in Lambayeque and an irrigation institute carry his name. Sutton's plans for constructing irrigation infrastructure should increase the national food production and develop the domestic market. The projects were to be self-financing. His idea was to build reservoirs, permanent head-works and main canals to bring water to future irrigated lands. This new land was to be sold in parcels of about 4 hectares, thus creating small, but commercially viable farms. The idea was taken from similar projects in the USA and Australia. Sutton started such a project in 1920 in Cañete 150 km south of Lima. In the Pampas del Imperial project 4,000 ha were sold to 600 families at a price covering the construction of the irrigation works and expropriation of the land. The land was sold within 24 hours and the land became highly productive, despite the lack of government aid. The Cañete project was considered a good demonstration project. The next project to be executed was the large Olmos project expanding the Chancay-Lambayeque irrigation system.

In October 1928 the officials of Leguía, together with middle sized landholders in Chancay-Lambayeque, organised an important congress in Lambayeque: '*The First Congress of Irrigation and Colonisation in the North Coast*' (Anon. 1929, Urban 1990). The congress was to give a firm impetus to the Olmos project and the modernisation of agriculture in the North Coast of Peru. An impressive congress building and an exhibition ground were constructed. In the proceedings of the congress more than 230 papers are presented. The papers address a wide variety of themes on agriculture, irrigation, land reclamation, education, and other social and economic issues[17] (Anon. 1929).

[17] Some examples of titles of papers: 'the function of speculation', 'the costs of progress', 'women and economics', 'what are the social costs of cheap day-labour?', 'the level of living in Lambayeque and Piura', 'the architecture of rural schools', 'the importance of teaching foreign languages', 'must the government stop the migration from Asia?', 'the relation between agriculture and the problem of demographic growth', 'colonisation and women', 'differences between small and latifundio cultivation', 'increasing rice production by rotation with leguminosae', 'engineering: is it a science or an art?', 'the organisation of irrigation', 'water losses in canals', 'the measurement of water as instrument in water management', 'the value of irrigation water', 'malaria as work accident', and 'history of agriculture in the Piura and Lambayeque' (Anon. 1929).

On the exhibition ground, several types of houses, crafts, and agricultural tools were shown, all related to the idea of modernisation of the rural areas. In the light of the topic of this study one item exhibited is of special interest. Its picture is shown in the proceedings (Anon. 1929). It is a wooden construction of a closed box hovering 10 metres above the ground supported by a framework of wooden posts. The subscript under the picture reads "*Tank erected on the exhibition ground to spread the concept of the* módulo de riego, *formulated in the new ordinances on the water distribution in Lambayeque*". On the tank in the picture is painted: "*This tank contains the volume of 7.75 x 7.75 x 10 metres, thus having a capacity of 600* m^3. *With this one could irrigate one hectare in whatever part of the world, even more so in our Department because the natural impermeable sublayer in many parts can be found only one foot under the surface. In the Department there are already a lot of farmers that have learned to irrigate with less than 400 cubic metres per hectare.*"

Among the most important speakers for the congress was Sutton. Clearly the local small and middle-sized landowners and the local government favoured the Olmos project to be executed in the Chancay-Lambayeque valley. Sutton was a firm promoter of the project that would increase the irrigated area from 65,000 to 300,000 ha at a cost of only half the investments per hectare made in the demonstration project in Cañete. The project included reservoirs, drains, and extension of the existing canals and tunnels to bring water from the Atlantic watershed to the Pacific side of the Andes. Sutton favoured a change from sugarcane and rice to less water requiring crops and small landholdings. One work had already started in 1920: the building of the permanent headworks of the main canal Taymi in Chancay-Lambayeque: La Puntilla. The rest of the Olmos project works was abandoned in 1930 at the fall of Leguía, only to be picked up again for political reasons by the Fujimori regime in the 1990's.

Not withstanding the pressure from the government engineers, many of the older practices of water distribution continued in Chancay-Lambayeque after 1928. The water was divided proportionally ('*reparto*') between the two *Comunidades de Regantes* (50%-50%) in high river flows and rotated ('*mita*') (6 days - 8 days) in times of low water flows. This was much to the anger of the engineers who found this a 'non-technical' way of water distribution: ".. *que es ajeno completamente al carácter técnico y científico..*" (Tupac 1929:726). After the fall of the Leguía government in 1930 the *haciendas* took over again the management of the irrigation systems (Urban 1990).

The governments between 1930 and 1963 were conservative and did little to intervene in the management of the irrigation systems. Some smaller projects were executed. Only in 1963 the government of president Belaúnde started with legislation and projects that interfered with the existing irrigation systems. Belaúnde started the construction of the Tinajones reservoir in Chancay-Lambayeque (paid by the West-Germans) and drew up a land reform law in 1964, which interfered with the land and water rights of the *haciendas*. This reform law introduced volumetric water allocation and charging. Nevertheless, this law had little effect on water management and very little land was redistributed (Cleaves and Scurrah 1980).

2.3.5 The Agrarian Reform of 1969

A sweeping land reform did take place under the guidance of the military regime of General Juan Velasco that took power in 1968. Throughout Peru, most *haciendas* bigger than 150 ha. were expropriated and converted into co-operatives. By 1975 10,000 *haciendas* with 7.5 million hectares (out of the targeted 10.1 million hectares) had been expropriated and distributed to about 254,000 families (Alberts 1983). *Hacendados* could escape somewhat this surprise attack on their lands by subdividing their land and giving pieces of 150 ha to family and friends. However, the social and economic impact of the land reform was substantial. The labourers of the *haciendas* became the members of the co-operatives. The *hacendados* were compensated with shares in government enterprises that later proved to be worthless. Most *hacendados* left agriculture, but some continued with the land they were allowed to possess: a maximum of 150 ha (and later maximum 50 ha in the Coast). The co-operatives generally maintained the commercial production patterns of the *haciendas* that preceded them. It must be noted that the most marginal groups in society, the Comunidades Indígenas were not considered in the land reform, and only got little land, so their position remained as marginal as before the land reform. (Cleavas and Scurrah 1980)

In Chancay-Lambayeque three sugarcane co-operatives and 23 co-operatives producing different crops like rice, maize and cotton were formed (the biggest 4000 ha and the smallest 200 ha), with in total 45,000 ha, leaving about 30,000 ha to private small and middle-sized landholders. In Jequetepeque the big *haciendas* were moulded into six co-operatives. However, much of the middle-sized landholdings (some 20 above 200 ha each) were left untouched. These middle-sized landholdings (or shall we say small *haciendas*) would play an important role in the local (water) politics. Why many of the middle-sized holdings were left untouched by the military is unclear. Most probably personal contacts between the military top in Lima and the landed elite in Jequetepeque helped. In total 16,000 ha was in hands of co-operatives and 20,000 ha was in hands of small, middle-sized, and larger holdings. Many violent conflicts occurred between the *Comunidades* of Chepén, San Pedro and Jequetepeque on the one side and the *hacienadas* and later co-operatives on the other side over water rights (Collin 1984).

Apart from the land reform, the Velasco government also installed a tight control on the commercialisation of inputs and outputs of agricultural production. Together with the Agrarian Credit bank (Banco Agrario), the State enterprises controlled the production process of the co-operatives and individual farmers. ECASA (Empresa Comercial de Arroz S.A.), for example, set a fixed price for rice, provided inputs through a credit of the Banco Agrario, and finally purchased and distributed the rice on a national scale. The high and stable price and purchase-guarantee stimulated the expansion of the cultivation of rice.

Together with the land reform also a new water law was issued in 1969. The new water code (Ley General de Aguas, Decreto Ley 17752) was a radical change compared with the conservative *laissez faire* water law of 1902. It incorporated a lot of the ideas on volumetric allocation and pricing already formulated by the Ministry of Advancement in Lima in the period 1910-1930, and the ineffective land reform law of 1964. Details of the law are discussed in Chapter 4, but the main points are:

1. All water became public domain and the State decided on its use (by means of giving concessions for use). The State should see to it that water was used for the general benefit of the society.
2. Local government officials of the Ministry of Agriculture: *Administración Técnica de Distrito de Riego* (ATDR)[18] would do all the management of the water from headworks to the entrance of co-operative or privately owned plot.

[18] The water law of 1969 uses the term *'Autoridad de Aguas'*: this only became the ATDR in 1989. But for reasons of clarity we will use only the term ATDR.

3. Water was allocated (and charged) in exact volumes according to the area of certain crops authorised to grow. The ATDR establishes cropping zones: *Plan de Cultivo y Riego* (PCR). The allocation was no longer a fixed flow, but a flow based on presumed crop water requirements and the planned cropping pattern. Crop water requirements were established by the ATDR in Chancay-Lambayeque at e.g. 15,000 m^3/ha for paddy, and 7,100 m^3/ha for maize at field level per growing season. These volumetric quotas were called '*modulos de riego*'.
4. In article 29 the water law established two different types of water titles: *licencia* (permanent water right) and *permiso* (only right to excess water). Besides the area with a planned cropping pattern (with *licencia*), the co-operatives had fallow land, which they could irrigate in case of abundant water flows in the river (*permiso*). Individual plots were also assigned either *licencia* or *permiso* water use rights.
5. The water users were organised in *Comisiones de Regantes* that together formed a *Junta de Usuarios* in each Irrigation District. These organisations only had a small role in the water management.

In fact the Velasco regime wanted and realised a complete control over water. The ideas on volumetric water control put in the new water law were not new. Leguía and Sutton had already formulated them between 1910-1930. Furthermore, many of the ideas were already promulgated in the 1964 agrarian reform law. However, the ideas of Sutton and the laws of 1964 were only implemented very partially because of the power of the *haciendas*. With the land reform of 1969 the big *haciendas* disappeared from the scene and the State gained much influence because the ATDR s in the Coast got the means and staff to allocate and distribute the water to the smallholders and the newly formed co-operatives. The co-operatives[19] were less strong in defending their interest compared with their preceding *haciendas*. In the *Junta de Usuarios* the co-operatives had only one vote, so the ATDR officials, together with the biggest landowners, controlled the water in the irrigation systems in the Coast.

The ATDR employed staff for the management of the complete irrigation system. In the central office, engineers would plan the irrigation season, draw up the *Plan de Cultivo y Riego* (PCR), and take operational management decisions. The field staff would distribute the water in the main, secondary and tertiary canals (this last only in case of individual plots). In the case of a co-operative the members or hired personnel of the co-operative would distribute the water inside the boundaries of the co-operative. Payment of the Irrigation Service Fee (ISF) was automatic in case a farmer (or co-operative) would obtain credit from the Banco Agrario (which almost all did). The Bank would simply withhold the due fees from the sum paid at the selling to the State purchasing enterprise. Although the fee recovery rate was close to hundred percent, the State gave a lot of subsidy for the operation of the irrigation systems.

Farmers at present hold opposing views on the time of the Banco Agrario and ECASA. Some would like to go back to the security of the bureaucratic system. Others hate the Velasco period for its corruption and top-down planning. Many farmers reported that payment of bribes to get a loan from the Banco Agrario or water from the ATDR was common practice. A full evaluation of this period is not within the scope of this research, but in general two conclusions can be drawn: livelihood and general economic well being was better in the period 1970-1980 as compared to the neo-liberal period 1990-2000. On the other hand the

[19] The State controlled the co-operatives and up to 50 percent of the members perceived the co-operatives to be owned by the State and not by the members (Gonzales 1985)

costs of the bureaucracy[20] and the declining productivity of the co-operatives made the socialist system economically unsustainable.

Two big irrigation infrastructure projects were executed in the Velasco period (1968-1975): the Chira-Piura and the Majes projects. Investments in irrigation projects rose from 38 million US dollar in 1971 to 334 million in 1975 (Urban 1990).

In 1970 the Tinajones reservoir was put into use in the Chancay-Lambayeque irrigation system. The Tinajones project was part of the original Olmos project designed by Sutton. The Chancay-Lambayeque system was expanded by 40%: from 79,750 ha in 1965 to 110,475 ha in 1995, although the Tinajones project brought an increase of only 24% more river discharge with the Chotano (1965) and Conchano (1983) tunnels and a relative small storage reservoir called Tinajones (1970) (Urban 1990, IMAR 1997b). In fact the modernisation of the system increased the overall security of water supply, but decreased the volume of water available to the head and middle reaches. This reallocation of water seems to have been possible only because the local elite and new co-operatives had lost the power to defend their water rights from government interference. The government used the new water to allocate it to new smallholders in the Valle Nuevo, north of the existing system, to win political support.

The Jequetepeque system kept its original command area with accompanying abundant water availability per hectare. Here no reallocation of water rights occurred, probably due to the still strong political power and close ties between the landed elite of middle-sized landholders with the military regime in Lima.

2.3.6 Parcellation of the co-operatives (1980-1985)

The functioning of the co-operatives, formed out of *haciendas* in 1970, deteriorated during the period 1975-1980. In the first years after their formation the high river discharges and the high prices for rice maintained the economic performance of the former *haciendas*. However, these good times resulted in management practices that could not be sustained in the more difficult years. The members of the co-operatives had little motivation to provide labour for the co-operative. They preferred to hire external labour. Also they were over concerned with the provision of good salaries, schooling and housing at the cost of investment in the productive means of the co-operative. Around 1980 most co-operatives went bankrupt. Between 1980 and 1985 all non-sugar-cane producing co-operatives chose to parcel their land and give all members a private plot to cultivate. (Gonzales 1985, Oré 1989). Especially after the floods of the El Niño of 1983 many co-operatives broke down.

For the two irrigation systems this implied a conversion of the collective water rights of the co-operatives to water rights for in total 22,500 individual titleholders in Chancay-Lambayeque and 12,000 in Jequetepeque. Each co-operative could decide how to divide the land and the water rights. In some co-operatives each member got one plot with two parts: one part (e.g. 3 ha) with a permanent water right and another part (e.g. 2 ha) with an excess water right. In other co-operatives two different zones were created, and each member would get a plot in both zones. The average size of the plots was some 5 ha, but the exact size was different in each co-operative. The size depended on the number of members and the size of

[20] Public sector spending rose from 24 % of GNP in 1967 employing 270,000 civil servants to 50 % of GNP in 1977 employing 577,000 civil servants; in the same period public foreign debt increased from 945 to 6,900 million US dollar (Cleaves and Scurrah 1980).

the land of the co-operative. In some co-operatives the size of the plots was different according to the number of years a member had worked for the co-operative or the quality of the soils. The different outcomes of the parcellation had important consequences for water management; this will be dealt with in succeeding chapters.

In the North Coast the plots were assigned exclusively to men, because women were not considered workers on the co-operatives regardless of the important seasonal labour they provided (Huber 1990, Deere and León 1998). Today, about twelve percent of the plots is owned by women through inheritance (Hidrogo 1996).

An exception to the parcellation were the three big sugarcane co-operatives situated in the head-end of the Chancay-Lambayeque system. They remained collective enterprises. It is easier to organise collective labour for sugarcane cutting and transport with a plantation-like management.

The massive parcellation had a big impact on the tasks of the ATDR. Before the parcellation they allocated, charged and distributed the water to the gate of the co-operatives (and small and middle-sized landowners). After the parcellation the ATDR saw its workload doubled as now water was to be allocated, charged and delivered to a double number of individual plots. The budget of the ATDR was not increased, and with the heavier workload some tasks, like maintenance of the infrastructure, became less attended.

In Jequetepeque the Callito Ciego reservoir and Talambo main canal were constructed between 1985 and 1990. The reservoir with a useful capacity of 400 million cubic metres increased considerably the reliability of the water supply to the valley. However, contrary to the expansion in Chancay-Lambayeque with the Tinajones reservoir, the irrigated area in Jequetepeque hardly changed. The landed elite, again, proved to be politically powerful enough to secure their privileged access to water.

2.3.7 The irrigation management turnover (1989-1998)

The economic crisis of the late 1980s during the government of Alan Garcia aggravated the problems of the ATDR caused by the parcellation of the co-operatives. The government could simply no longer subsidise the operation and maintenance of the irrigation systems. A turnover of the management and financing of the systems to the users seemed to offer a solution.

In 1989, by means of law D.S. 037-89-AG, Alan Garcia dictated a turnover of the water distribution, maintenance and financing of the irrigation districts from the ATDR to the water users organised in *Comisiones de Regantes* (secondary units) and their federation; the *Juntas de Usuarios* (main system). It is important to note that the allocation of water both at field and at system level were not transferred to the users organisations. The ATDR was to keep performing the task of drawing up the crop water allocations (PCR) for all plots. Although the law was quite clear, the ATDR continued to deliver water and finance its personnel. The leaders of the *Comisiones* and *Juntas* were not willing to take over the management of the system and the users were not willing to pay a ISF that would cover the operation and maintenance costs (Oré 1998).

In 1990 Alberto Fujimori won the national elections. He was to speed up the process of turnover. Fujimori established new relations with the international financing institutions, which had been broken in the Alan Garcia times. The World Bank came in with a number of large loans. Many of the loans went to infrastructural projects: roads and irrigation systems. The World Bank clearly pushed for neo-liberal reforms. They promoted the Irrigation Management Transfer and the change of the water law so as to introduce a water market (e.g. see World Bank report on irrigation in Peru by Thobani (1995)). In 1996 the World Bank issued a loan of 85 million dollar for the rehabilitation of irrigation systems and training of local leaders with the explicit aim to "*...help reduce the role of the public sector in irrigation*" (Irrigation Subsector Project: PSI, World Bank 1996).

In Chancay-Lambayeque in 1990 the *Comisiones* were ordered to establish and collect their own water fee. However, the ATDR continued to distribute the water, and consequently the *Comisiones* had no means to withhold users that did not pay their fees. This resulted in low fees and also a low fee recovery. Meanwhile the ATDR got fewer staff and stopped the maintenance activities completely. (Chinchay and Sijbrandij 1999)

In 1992 the feeder canal to the Tinajones reservoir was damaged. Urgent maintenance was needed, ... but who was to pay? The government made it clear that the State would not pay but gave a credit. To give impetus to the turnover process the government of Fujimori issued a law to have elections to re-new the boards of all *Comisiones* and *Juntas* (037-92-AG). This was the start of the real turnover. The new boards were willing to take the responsibility to deliver the water and charge a fee that would cover their expenses for operation and maintenance. The local NGO IMAR Costa Norte worked hard to train the new leaders, introduce an automated financial administration and made an inventory of the infrastructure. IMAR helped the *Junta* to convince the users of the need to pay an increased ISF with excursions to the main infrastructure and the daily '*Voz del Usuario*' program on the local radio. (Chinchay and Sijbrandij *ibid.*)

The turnover was done in steps: first the O&M in the secondary units (sebsectors) was transferred to the *Comisiones de Regantes*. Some years later the management on system level was transferred to the *Junta de Usuarios*. The *Juntas* were given concessions of ten years to the use of the water and the infrastructure. In 1993 the main system in Chancay-Lambayeque was turned over the *Junta de Usuarios*. They created a special private, but non-profit, enterprise: ETECOM S.A. to operate and maintain the main canal Taymi and the reservoir Tinajones. This enterprise also collected the ISF.

In Jequetepeque the main system was turned over to OPEMA in 1998. As in Chancay-Lambayeque this enterprise was in charge of the operation and maintenance of the reservoir, intake works and main canal. The functioning and effect of ETECOM and OPEMA will be dealt with in succeeding chapters.

The main problem for the water users' organisations became the collection of the ISF, because the *Comisiones* and *Junta* had to finance the complete Operation and Maintenance (O&M) by means of the collected ISF, without any government subsidies. The *Junta* of Chancay-Lambayeque decided in 1993 to introduce payment per volume of water delivered to the field. The farmers were used to a payment based on irrigated area, but accepted the change in payment because the main canal was at the point of breakdown and funds were needed immediately for repair. Furthermore, the price per volume was quite low, so that in total they did not pay more than the flat rate. The ensuing years the fee was increased annually, so that after some years the collected fees were sufficient to cover O&M costs. The ISF in 1999 was about US$ 2 for 576 m^3 (for comparison: US$ 3 is a daily wage of a farm worker and total rice growing costs are about US$ 1,000 per hectare). In Chapter 6 the setting of the ISF, the fee recovery and the spending of the money will be dealt with.

The *Junta* of Jequetepeque decided to keep the payment per area according to the type of crop, but enforce payment in parts during the growing season to be able to sanction non-payment with cutting off the water supply. (They themselves see this also as volumetric payment, although the amount to be paid is not directly related to the actual water use at field level as it is in Chancay-Lambayeque.)

How this turnover affected the operation, maintenance and financing of the irrigation systems will be demonstrated in the subsequent chapters. In brief, this study shows that the operation (delivery compared to planned volumes) was executed quite well; that the maintenance was still partly subsidised, but also done quite well; and that the ISF to be paid and the fee-recovery increased sharply. The main problem became the cancelling of the three elections of the boards of the *Comisiones* and *Juntas* by Fujimori. Only in 2001 were the first elections held since 1992.

2.4 Present agricultural production systems

2.4.1 Agribusiness and recent neoliberal politics

The administrative and economic context in which farmers had to operate changed dramatically with the start of the Fujimori government in 1990. Since the land reform in 1969 the government controlled the market in a 'socialist' fashion. The co-operatives and private landholders operated in an economic environment that was highly regulated: the prices were fixed, state organisations provided credit, inputs, extension services and bought the produce.

The fixed prices already changed in 1986 with the ending of the State rice-purchasing enterprise ECASA. The State-financed rural credit ended in 1991 with the closing of the Banco Agrario. The extension and research centres were privatised (and now sell HYV seeds and are sponsored by Bayer). During the course of the 1990s more and more neo-liberal measures were taken. The import taxes on rice and sugar were lowered, the irrigation systems were transferred to the water users' associations, and direct subsidies to farmers and co-operatives were abandoned. Other important policies were the official registration of land titles, which enabled buying and selling of private land, but also enabled the use of the land title as collateral for a loan.

Peru increased the import of all important food products[21]. The neo-liberal measures heavily affected the rural areas. The support for small landowners diminished and the legal possibilities for land accumulation increased. Many small farmers commented to me in informal talks: "*El gobierno ha abandonado el campo*" ("the government has abandoned the rural areas"). Large agricultural enterprises, with international investments, grow export-oriented crops like asparagus, mangos and maracuya.

[21] Food imports increased from US$ 460 million in 1990 to 566 million in 1999. (Source: www.worldbank.org/data/)

What the government of Fujimori did do was make investments in infrastructure: roads and main irrigation works, and sell new irrigated land to multinationals like Dole and Delmonte. The new irrigation infrastructure was financed with loans from Japan and the World Bank[22]. The latter co-financed the 'Proyecto Subsectores de Irrigación' (PSI) project that did much of the rehabilitation of the irrigation infrastructure damaged by the floods of the El Niño rains in 1998. The local offices of the Ministries of Agriculture also have some small credit programmes for beans, and hire out tractors at reduced prices. Overall the support for farmers is minimal. The efforts increase before the elections, which makes clear that they are 'populist' subsidies.

Commercial banks have provided some credit to private farmers. However, the risk was too big as many farmers did not pay off their debts. A co-operative rural bank was established, partly financed by the *Junta de Usuarios*: the 'Caja Rural Cruz de Chalpón'. This bank provides credit so some small rice growers.

New key players in the local economy became the local combined rice huskers and traders, known locally as '*molinos*'. These are private enterprises that buy unhusked rice, husk and polish the rice, store it and sell it in the major towns throughout Peru. The *molinos* are situated along the main access roads of Chiclayo, Ferrenafe and Chepén. They consist of a square terrain of about 100 x 100 metres and are enclosed by a high wall. Inside are a small office and the actual husking and polishing installations. The biggest part is just an open square, which is used to dry the rice before husking. In Chancay-Lambayeque there are about twenty big *molinos*. Four or five are real strong players in the field, but none has the absolute domination of the market. In Jequetepeque there are about four big *molinos*. However, one *molino* (including an agricultural inputs shop) is clearly the most dominant. It is called 'El Cholo'. Besides husking and trading rice the *molinos* provide credit to small rice producers. As will be seen below, the interlinked market of credit and rice trade provides the *molinos* with a very strong position vis-à-vis the farmers.

2.4.2 Four types of farming enterprises and the sugarcane co-operatives

The production strategies of the types of farming enterprises are differentiated mainly by the access to land and irrigation water. Basically, five different farming systems can be distinguished. Of course there is large variation between individual farm holdings within each group, but the five categories give a rough indication of the types of farmers in the two irrigation systems. Each production type is more or less located in specific areas within the irrigation systems. The rice farming systems (including smallholders (type 1) and bigger rice growers (types 2 and 3)) are situated in the middle reaches of Chancay-Lambayeque and throughout the Jequetepeque irrigation system. The maize and bean growers (type 4) are found in the tail-ends zones of both systems. The sugarcane co-operatives (type 5) are located in the head-end of the Chancay-Lambayeque system. Table 2.3 shows the landholding distribution in both irrigation schemes. In the sample areas for the research only landholdings smaller than 50 ha were present. However, the landholding sizes do not show that some entrepreneurs lease a lot of small plots that together might add up to more than 50 ha.

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[22] Foreign debt increased from 20,064 million US dollars in 1990 to 28,117 million in 1999. (Source: www.worldbank.org/data/)

Table 2.3: Landholding distribution in the two systems (Source: IMAR 1997b, *Junta de Usuarios* Jequetepeque)

	Chancay-Lambayeque*		**Jequetepeque**	
	Ha	% of holdings	Ha	% of holdings
Smallholders (0-3 ha)	18,752	30	11,200	26
Medium sized landholders (3-10 ha)	27,397	43	23,620	56
Large landholders (10-50 ha)	7,842	13	6,130	15
Ex-*haciendados* and new landlords (>50 ha)	8,657	14	1,200	3
Sugarcane co-operatives	25,476**	(3 coops)	0	0
Total	88,124	100%	42,150	100%

* Data only for '*licencia*' landholders.

** This is the total area potentially to be cultivated by the co-operatives, however, due to economic and management problems, each year less area is actually cropped. It is estimated that more or less two-third of the area is still cropped.

Small rice growers

More than 80% of the irrigated land in the Jequetepeque system and about one third of the irrigated land in Chancay-Lambayeque is cultivated by small rice growers. Cultivation of rice has a long history in both valleys. It was a commercial crop in the *hacienda* period and was promoted and subsidised by the socialist government between 1970 and 1990. The holdings are between 3 and 8 hectares. On average 5 ha in Chancay-Lambayeque and 7 ha in Jequetepeque. Most owners have kept their land holdings undivided since the parcellation of the co-operatives in 1983. In some areas fragmentation of land holdings has occurred due to inheritance. In other areas large land holdings have emerged due to selling of land by indebted landowners and buying of these lands by rich entrepreneurs. About ninety percent of landowners are male[23]. Those women who do inherit land keep their land title after marriage (or cohabitation, as many couples do not officially marry). The family structure and the system of inheritance are quite complex and very diverse. It was not possible to gain much insight into this subject in the course of this research.

Many different household compositions can be found. In some cases the household comprises the 'standard nuclear family' (man-wife-small children). In many cases the household composition is more complex and includes adult offspring and other relatives. In many cases the landowners themselves are quite old (53 years on average for all water users in Chancay-Lambayeque). In case of older landowners, and/or a female headed household, a son (or in rare cases a daughter) of the landowner will conduct the farm enterprise. The household composition varies over time, and many members will move between an independent household in a town and the farm-household. Usually one family member is the manager of the farm enterprise. In external relations the male head of the household takes the lead. Apart from the management (that is taking decisions on crops, input-use, obtaining credit, and labour and the supervision of the labour) the family members also provide labour. However, it is considered an 'ideal' to provide as little labour on the fields as possible. Even smallholders of 3 hectares might try to hire the labour for the hard work in the field. Only if financial conditions force the family to provide labour on their own fields they will do so. In this sense they do not copy the model of the European farmer-family, who own at least some of the farm-equipment and will provide most of the labour themselves. Instead, the small farmers

[23] This data for Chancay-Lambayeque was provided by Hidrogo (1996): it is assumed that this applies also more or less to Jequetepeque. It was explained earlier in this chapter that ninety percent of the small landowners is male - despite the practice that daughters do inherit land - because the co-operative land was given to male members only.

copy the ideal of the *hacienda*, in which the land owning family provides as little labour as possible. Nevertheless, because of the economic conditions, the members of families that own less than ten hectares will normally work almost full time at the farm.

The rice-growing season is from December to June. The season is determined by the availability of water in the rivers and the air temperature: the minimum temperature should not drop below 15 degrees centigrade. As temperatures from July to January can easily drop below 15 degrees at night, especially in the locations less than ten kilometres from the ocean, temperature is a strong determinant for the spatial and temporal location of rice growing. River flows are high from February to May. Most rice growers will try to grow a second crop after the rice is harvested. This can be beans in association with maize, or a mono-crop of one of them. Whether or not a farmer will grow a second crop depends on the water availability in the river, and other factors like availability of credit and/or labour. The second crop is normally only irrigated once: using soil moisture remaining from the previous rice crop.

The rice production is characterised by a 'high input - high output' system. Yields are generally high: on average the 30 interviewed farmers in Chancay-Lambayeque had 6.5 $t.ha^{-1}$ unhusked rice. This results in about 4.5 $t.ha^{-1}$ of husked rice. In the five yield measurements in Jequetepeque the yields were 10.0 $t.ha^{-1}$, resulting in about 7 $t.ha^{-1}$ of husked rice. The seeds used are High Yielding Varieties (HYV), from the International Rice Research Institute in the Philippines (IRRI), via CIAT in Colombia. The HYV are first tested and modified in research and extension centres in Peru (in Chancay-Lambayeque: Vista Florida near Ferreñafe) or imported by local seed producing entrepreneurs. The local varieties named 'Viflor', 'NIR' and 'Amazonas' are based on IR-8, IR-43, IR-930 and TETEP. The varieties have high potential yields: up to 10 or even 12 $t.ha^{-1}$ due to the relative good climate with many hours of sunshine during the growing season. They are not hybrid varieties, so farmers can cultivate their own seeds. However, seeds obtained from special local seed producing enterprises usually give better yields. About half of the farmers keep part of their harvest to use as seeds the next year. Once in about two or three years they buy new seeds or trade seeds with another farmer. Others buy seeds every year from a *molino* or specialised private enterprise. Also 'Vista Florida', the former State extension and seed breeding centre, sells seeds.

In most cases the land is ploughed by tractor. The tractor and plough, including the driver, are hired by hour from private owners of machinery. In some cases ploughing is done by horses. Land is first ploughed in dry condition. After a first flooding the land is levelled by hand or oxen or horse. There is not really 'puddling' as practised in Asia to decrease the percolation, although the levelling by horse or oxen might have more or less the same effect.

The rice nurseries are prepared at a lower part of the field, and in areas where water distribution is still unreliable in the beginning of the growing season a field next to the nursery is used as a reservoir ('*patera*', literally 'duckpond'). The *patera* is filled during an irrigation turn and the water is released bit by bit to provide the seed bed with the exact water layer required. Also water users share an irrigation turn to obtain smaller flows and more frequent turns. Preparing a good nursery is considered a difficult job for which a lot of skill and experience is needed. It is a job mainly executed by men. Transplanting is done mainly by hired day labourers who come from the region and people that temporarily migrate from the North Coast and Sierra. Men, women and children do the hard work of transplanting.

The use of nitrogen fertiliser is high: on average about 300 kg N ha^{-1}. Besides nitrogen fertiliser also other fertilisers are applied containing phosphorus and potassium. The fertiliser is bought from local shops and applied by hand. Also all kinds of 'foliar fertilisers' are applied on the rice leaves. Many farmers strongly believe that these 'hormones' make the crop 'stronger'. Pesticides and fungicides are used very intensively[24] (see Table 2.4).

Table 2.4: Use of inputs in rice. Percentages indicate the number of farmers in each sample that applied more or less the officially recommended doses (Source: own survey)

Product	**La Ladrillera and La Colorada**, CR Lambayeque, Chancay-Lambayeque (n=30)	**Pueblo Viejo, La Granga and Farfancillo**, CR Guadalupe, Jequetepeque (n=29)
Nitrogen fertiliser	280 kg N ha^{-1}	325 kg N ha^{-1}
Foliar fertiliser	55 %	62 %
Insecticides	62 %	93 %
Fungicides	38 %	48 %
Herbicides in the nursery	83 %	69 %

Most weeding in rice is done by hand. Weeding is done three times during the growing season. The first time requires the most labour and is done by hired labourers. The next weeding takes less time and is mostly done by family members, including children.

The differences in input use between the sample farmers in Chancay-Lambayeque and Jequetepeque as seen in Table 2.4 can be explained mainly by the environmental conditions. As in Jequetepeque there is more water than in Chancay-Lambayeque, in Jequetepeque they require less herbicides because weeds can be controlled better by a standing water layer. However, in Jequetepeque they need more insecticides and fungicides because of the more humid environment in which insects and fungi develop. The increased use of fertilisers in Jequetepeque might be attributed to the monopolist *molino* in Jequetepeque, which aggressively promotes the use of inputs compared to a more competitive market in Chancay-Lambayeque where credit, input and produce markets are more separated.

The rice fields are irrigated with water supplied by the irrigation system. No groundwater is used. The basins are flooded either by irrigation turns each 15 days (Chancay-Lambayeque) or by continuous flow (Jequetepeque). The water is of good quality. Further information regarding irrigation will be elaborated in the next chapters.

Harvesting is done mainly by hand (with a sickle) by men and women. Some estimated twenty percent of the fields were harvested with one of the few combine harvesters, which are hired from local machine owners. This latter method was used more widely some ten years ago, but due to the lack of capital and the relative cheap labour the combine harvesters are slowly replaced by manual harvesting. The paddy is left on the field to dry for one or two

[24] Most common pests are all sorts of worms, leafhoppers, stem borers, caterpillars and bugs (*Spodoptera frugiperda, Diatraea saccharalis, Rupela albinela, Lissorhoptrus oryzophilus, Hydrellia spp*). They are combated by hand spraying of insecticides produced by Bayer, BASF, Agro Klinge, Rhone-Poulenc, Farmex and Cyanamid. Farmers (only male) do not wear any protective clothes while spraying. Most products are not very toxic, but BASF still sells the extremely toxic Parathion. Fungal diseases commonly encountered are: Brown spot (*Helminthosporium*) and Blast (*Pyricularia oryzae*). They are combated with spraying of various moderately toxic fungicides, produced by the same multinationals. The most important aquatic weeds encountered in the rice fields are *Cyperus rotundus* and *Echinochloa crusgalli*. Herbicides are used almost exclusively in the nursery, and are also moderately toxic, only Agro Klinge stills sells the highly toxic Paraquat.

weeks. The rice is threshed with special machines ('*trilladora*') that are powered by tractors. A part of the rice is threshed by hand ('*azote*': a bundle of rice is beaten against a special wooden board). This is done either to obtain some rice for home-consumption before the big part of the rice is ready to be trashed mechanically, or to obtain undamaged grains to be used as seeds the next season. The paddy is stored in the house of the owner or sold immediately to a trader or *molino*. Transport is mostly by pickup truck. Some part of the rice is set aside for home-consumption. As prices are low during and directly after the harvest season, the farmers generally try to store the rice for some months to be able to sell the rice at better prices. Due to the high interest rates this is generally not possible and rice is sold immediately. The rice is husked and polished at a *molino*.

Besides access to land and irrigation water, credit is one of the main constraints (see also next section). The production costs are high compared to the benefit (see Appendix III for a detailed overview of the production costs and benefits). The interest paid is an important factor in the production costs. In total, the return to money invested in one hectare of rice land is US$ 300 or 25 percent. An average family with eight members, including children, which owns five hectares will have an income of about US$ 1500, and in addition the labour the family members can provide on their own land. This labour input can be estimated at 300 working days (3 members fully employed during the rice growing season, daily wage of US$ 3), which amounts to US$ 900, making the total family income some US$ 2400. This seems to be a regular income, sufficient to send the children to school and build a modest house.

The above financial picture applies to a normal year and land with normal conditions. However, in some years there is not sufficient irrigation water, in other years the El Niño rains flood the land, and on some land salinity inhibits maximal crop development. The financial returns under these conditions are far less and farmers get indebted easily.

Many small rice growers also keep some animals and sometimes dairy cattle. It is considered a women's task to raise and sell chicken, ducks and turkeys. Also milking cows and selling the milk in the town is an activity mainly done by women. Rice growing is the main economic activity of most of the small rice growers: some younger family members might find other jobs, especially during the non-irrigation season. They migrate to towns to work in industry or service sector.

It must be stressed that the area grown with rice has increased significantly the last years. This was due to two processes. First the change from maize and beans to rice in the areas where maize and beans are grown close to the rice area. The salinity caused by waterlogging due to the rice growing inhibits the growing of maize and beans, and the ATDR and *Comisiones de Regantes* allow some formal, but mostly informal expansion of the rice growing area. The other process is that many smallholders close to the sugarcane co-operatives in the head-end had been growing sugarcane. But the smallholders decided to change from sugarcane to rice growing after the economic crisis in the sugarcane co-operatives (see below).

Large rice growers with own land

Both in Chancay-Lambayeque and in Jequetepeque some large landholdings can still be found. The holdings are somewhere between 50 and 100 hectares. These landholdings are remnants of the *haciendas* after the land reform of 1969. In Chancay-Lambayeque there are 48 holdings with more than 50 ha. In Jequetepeque there are 16 holdings with over 50 ha.

Some of these belong to the same family as the *hacendados* divided their holding among family members to be able to retain more land.

The families of the ex-*haciendas* still play an important role in the politics of the region. They have, of course, nowhere near the power held before the land reform, but they remain important, because they are better educated, still have a network of important political contacts and have more economic power because of their bigger landholdings. In Jequetepeque their participation in the regional politics and governance of the water users' associations is more pronounced in comparison with Chancay-Lambayeque.

They grow rice pretty much the same way as the small rice owners, except that they do not provide any labour of their own (family) on the fields. They hire overseers to contract and supervise the day labourers. In most cases these overseers are employed year after year. This is not a fixed contract, but if the landowner knows he can trust an overseer he or she will employ him each year. Bigger landowners might own some machinery like a tractor, and means of transport. Some have their own husking installation in order not to depend on a *molino*.

A special group of large landowners are the owners of the *molinos*. Some *molinos* have acquired vast tracks of land and grow rice themselves. Often, this rice is for seed production. Although they also have big landholdings, they are not like the ex-*hacienda* landowners, because the *molinos* also lease extra land to cultivate rice. They are much more capitalist entrepreneurs that seek to invest their capital as remuneratively as possible. The ex-*hacienda* big landowners normally do not lease extra land, and just try secure a good living from their land.

Large rice growers that lease land

During the last ten years new entrepreneurs have entered rice production. Although they also cultivate large areas with rice, their production system is quite different from the ex-*hacienda* landowners. The new entrepreneurs mostly have accumulated their capital outside the prime agricultural production sector. Most of them are rice traders, but some are engineers or professors from the local agricultural university. Each year they lease land from smallholders and hire overseers to contract and oversee day labourers. Land is normally leased for about US$ 300 per hectare. As can be seen in Appendix III this is about the same as the net benefit a small farmer can obtain from growing rice on his own field. This means that the leaser can only make profit by not having to pay interest, obtaining some of the inputs at lower prices, and selling the rice at higher prices. The small landowner is sometimes employed on his own land, but normally the entrepreneur pays the money and then can cultivate the land for one year.

The number of new 'leasing' entrepreneurs operating in both irrigation systems is hard to estimate. A very rough estimation is that about 100 new entrepreneurs in Chancay-Lambayeque and 50 new entrepreneurs in Jequetepeque were operating. The total amount of land an entrepreneur leases is somewhere between 20 to 500 hectares.

The production per hectare of the new rice-growing entrepreneurs is mostly higher than the production per hectare of the small landowners. They use good quality seeds, prepare and level the land well, and apply the recommended doses of fertilisers and insecticides.

Production can be as high as 10 $t.ha^{-1}$. Nevertheless, quite some failures were also noted. Some agricultural engineers found out that the practice of farming is more difficult than knowing the theories about crop growing. Some rice fields of these 'farming-engineers' looked very poor. The neighbouring farmers enjoyed themselves much in making jokes about these new farmers and felt increasingly proud about their own achievements in their fields.

Small maize and bean growers

The small maize and bean growers are mainly situated in the tail-end areas of the Chancay-Lambayeque irrigation system. They occupy more or less one third of the command area. They do not refrain from growing rice by choice. They would like to grow rice, but do not have the water right to grow rice or sugarcane. In the maize and bean area, land holding sizes are more differentiated in comparison with the rice growing area. More fragmentation due to inheritance has occurred, and also more buying and selling of land. In some areas also still new land can be reclaimed from sand dunes, saline or swamp areas. The production of the maize and bean growers is much more oriented at home-consumption. Some maize can be sold as fodder for the local poultry industry, but most is for family consumption. An exception is the growing of Pigeon pea. This pea is grown in contract farming for a local factory that cans and freezes these peas for export to the United States. Some one fifth of the bean farmers produce for this factory. The factory provides the inputs and buys the beans at the end of the season. The factory asks farmers not to apply insecticides after the peas start to grow, to reduce the chemical residues on peas that may hamper their export.

Two types of maize are grown: the HYV (e.g. Cargill C-701) and local varieties[25]. In about 75 percent of the fields maize is a mono crop. In about 25 percent maize is grown in association with beans and in few cases together with cotton. Yields vary according to the variety, amount of nitrogen applied and the application of irrigation water. Production is about 2.5 $t.ha^{-1}$ of grains. But often the whole plant is harvested and used as fodder.

Input use is much less in the maize and bean fields compared with the rice fields. However, here also quite some insecticides are used. Most labour is provided by the family members. Sowing and harvesting are typically female activities (sowing by women is believed to contribute to the 'fertility' of the plants). Land preparation, applying of fertiliser and insecticides, and trading and transport are male activities.

The production of the largest holdings might cover the food needs of the family, but normally is insufficient to provide for the minimal amount of cash needed. Some animals might be kept, like chicken, turkey, pigs, or goats. However, in most cases some family members will seek employment outside the own farm holding. This can be as day labourer for nearby (rice) farmers, or employment in the town of Chiclayo.

[25] Different types of beans are grown: Frijol (Bean: *Phaseolus vulgaris*), Caupí (Cowpea: *Vigna unguiculata*), Pallar (*Phaseolus lunatus*), Arveja (*Pisum sativum*). Most types have a short growing period of about four months, but one special type is the perennial Frijol de palo (Pigeon pea: *Cajanus cajan*). The yields of Pigeon pea are 4 $t.ha^{-1}$ of green peas plus 1 $t.ha^{-1}$ of dried peas. The perennial pea is grown in mono culture, the other beans are mostly grown in mixed plots with maize (Neciosup 1999).

The sugarcane co-operatives

A separate category of land use is sugarcane production. During the land reform of 1969 the sugarcane producing *haciendas* were transformed into co-operatives. They posses their own sugar refinery. Three co-operatives operate in the head-end of Chancay-Lambayeque: Pomalca (15,000 ha), Tumán (12,500 ha) and Pucalá (5,700 ha). In Jequetepeque no sugarcane is grown any more. Sugarcane is grown as a mono-crop. Net production is about 12 $t.ha^{-1}$ of refined sugar (thus coming close to the 'minimum' treatment in Appendix III). The members of the co-operatives elect a board to manage the co-operative. The board hires some engineers and professional managers to run the factory and the fields. The (male) members work in the fields, as truck drivers or in the factory.

Once sugarcane production was the most remunerative crop to be grown in the North Coast (see Appendix III). However, the last decade saw a decrease in the world market price of sugarcane, and the production efficiency of the almost antique refinery and demotivated co-operative workers became increasingly low. Once a sugar exporting country, Peru imported for 77 million dollars worth of sugar in 1998.

The economic situation in the sugarcane co-operatives caused increasing tension among the members in 1998 to 2001. The production fell every year: less fertilisers was used, less repairs were being done in the refinery, less investments were done to replace machinery, less areas of sugarcane were renewed. More and more members were sent home without a salary. The banks no longer gave loans to the heavily indebted co-operatives. The government wanted to privatise the co-operatives, but no one was found to buy and invest in the refineries. Members and pensioned members have shares in the co-operative. The value of these shares has decimated. Members accused the board of the co-operatives of mismanagement and in some co-operatives a 'shadow board' was operating. Conflicts during general assemblies usually were so violent that the armed forces had to be sent in to set people free and restore order. Since the crisis in the sugarcane co-operatives each year less sugarcane was cultivated. In 1999 about two-thirds of the land of the co-operatives was still under cultivation, albeit with less inputs than needed for optimal crop production.

Many smallholders now growing rice, used to grow sugarcane (as explained above). The co-operative would pay the smallholders with bags of sugar. In 1998 the co-operatives could not longer pay the smallholders. The government even issued a decree stating that the smallholders could not start any legal steps to make the co-operatives pay them the money owed. This bizarre measure was later discarded (La Industria 21-4-1999). At that moment the co-operatives owed about 12 million dollar to about 5,000 smallholders (La Republica 27-4-2000).

2.4.3 The credit-squeeze

After the closing of the Banco Agrario in 1991 small farmers could only obtain credit on the informal credit market. Some formal credit is given by the *Cajas Rurales*. In some particular cases also the commercial banks give credit to small producers, but both *Cajas Rurales* and commercial banks cover only a very limited part of the credit demand. Basically small landowners can get informal credit in two ways, apart from credit from family members (for overview of informal credit in North Coast of Peru see: Ugaz and San Miguel 1998).

The first is borrowing money from a local money-lender[26] (*habilitador*) or *molino*. The credit is obtained in cash and interest is paid per month. The farmer has to hand in her/his land title as collateral. In most cases the farmer is obliged to sell the crop at time of harvest to the *molino* or money-lender at a price fixed by the *molino* or money-lender to pay off the debts.

The second way of obtaining credit is through a local (rice) trader (*acopiador*). The trader gives a certain amount of cash during the growing season in return for a number of sacks of rice at harvest time. The local rice traders do not require collateral, they know the farmer personally ('*compadrazgo*'). In fact it is a pre-harvest sale (*venta de arroz en hierba* or *pre-cosecha*). The pre-harvest prices ('spot market' prices in economic terms) depend on the timing: the earlier the lower the price. For a four months period the price is about fifty percent of the price normally paid at harvest time. This means interest rates of up to twenty percent per month. Not only professional traders buy pre-harvest. So too do, for example, personnel of the Water Users' Associations or other local people. They know the farmers trust-worthiness, and know they can make the farmers pay off their debts.

The credit from the professional money-lenders and *molinos* is much more far reaching. The money-lenders and *molinos* create long-lasting ties of dependency with their borrowers. This means that, although there are many money-lenders and *molinos*, there is not really competition between the credit providers, which could lower the interest rates. The ties of dependency are created when a farmer needs credit for some reason. This need not be for production, it can also be consumptive credit.

The interest rates for informal credit are high: from 3 to 10 percent per month, in dollars. This together with the fixed low price[27] paid by the *molino* or money-lender means that many farmers cannot pay back the complete debt at the time of harvest[28]. This means that they have to pay back the rest of the debt with the next harvest. To obtain credit for the new production the farmer has to borrow money from the money-lender or *molino* she or he is indebted with, because they have the land title. In many cases this leads to a dependency relation that can only end by selling part of the land to write off all the debts or a loss of the complete land title to the money-lender or *molino*. Another way the *molinos* deal with the many farmers that have large debts is to 'lease' the land from the indebted farmer and use the land for one or more years to cultivate rice (or more often lease out the land again to a new entrepreneur). After some years, in which the farmer does not have any income from her/his land, the land title is paid back.

The *molino* might start to require all sorts of conditions for new credit from an indebted farmer: buy seed from the *molino* (for example, with good quality grains, but a less

[26] Some of the money-lenders had been employees of the Banco Agrario and took their network of clients with them to start their own business after the close down of the Banco Agrario.

[27] The price that is lower than the local 'free market' price, paid by the *molinos*, is called *'precio de castigo'* ('punishment price'), it is about ten percent lower than the 'free market' price at that moment paid to farmers who do not have a debt with the *molino*. However, this 'free market' price is also said to be manipulated by the *molinos*. Protest marches were organised both in Chancay-Lambayeque (24-6-1999) and in Jequetepeque (6-4-1999) against the assumed price-agreements of the *molinos*, and against the government that should intervene with buying rice at higher prices. The engineer of the ATDR in Jequetepeque, Roberto Suing, even officially accused the *molinos* of manipulating the prices, which was quite remarkable, not only because he is a government official, but even more because his brother, Victor Suing, is the owner of the biggest *molino*, called El Cholo, in Jequetepeque.

[28] See appendix III for the production costs, credit costs and benefit of rice production.

convenient, longer growing period for the farmer), and accept the service of an 'extension officer' working for agribusiness firms[29]. This increases further the debt-burden of the farmer, and the owners of the *molinos* get nice deals with the agribusiness companies like Bayer-Colombia and their local sellers. Some *molinos* even pay the ISF for the borrowing farmers. When I asked a local farmer in Jequetepeque about the power of the *molinos* in Jequetepeque, he responded "*Los molinos, ellos que casi hace el valle*" ("The *molinos* almost make the valley").

In this way many farmers now are heavily indebted and dependent on money-lenders or *molinos*. There is an extra risk involved in lending with a *molino*. The *molinos* use the land titles, given to them by farmers as collateral, to purchase credit with commercial banks. They bundle the land titles and obtain a much higher amount of credit per hectare (3,000 US$/ha) than the money they lend to the farmers (1,000 US$/ha). With the 'extra' money thus obtained they make investments (buy land) or speculate on the stock market. The farmer does not know that her/his land titles is not any longer in the hands of the *molino*. However, on paying back their debts many discover that the *molino* cannot hand back their titles to them upon paying off the debts. Sometimes it takes a year to get back the title. In Jequetepeque two cases have happened where the *molino* 'sneaked away' with all the land titles. It was rumoured that the *Molino* Wong, named after its owner, went bankrupt after having made unfortunate stock trading (others say because he gave too many loans without collateral). Mr. Wong fled from the country. The land titles of about three hundred farmers (in total 1,000 ha) were still in the hands of the commercial bank Mr. Wong got his credit from.

2.5 Conclusions

From the description of the Chancay-Lambayeque and Jequetepeque watersheds it became clear that the coastal zone is extremely dry and that water for irrigation of the coastal irrigation systems is provided by unpredictable and irregular rivers flowing from the upper catchments. Water use in the upper catchments does not significantly influence the downstream water availability.

The long history of irrigated agriculture makes clear that water has been used in large-scale irrigation in the coastal areas for more than a thousand years. Water became an increasingly scarce resource due to expanding *haciendas* and population growth by the 17th century. Since 1910 government began to interfere in the management of the irrigation systems. The balance between State intervention and autonomous local organisation in management of the irrigation systems fluctuated throughout the different epochs, but steadily the government gained influence, especially after the Land Reform of 1969. The turnover process in the 1990's weakened the State influence, but still the State remained with more influence in irrigation water management compared with the *hacienda* era.

The ideas of volumetric water allocation and payment, that had started to develop already with viceroy Toledo in 1577, were imposed on the irrigation systems from 1910 onwards. Until the Land Reform of 1969 volumetric water control was opposed by the *haciendas*. After the Land Reform the local irrigation office (ATDR) got the mandate and staff to really implement the volumetric water allocation and delivery. Volumetric charging was only

[29] The 'extension worker' will persuade the farmer to apply all sorts of fertilisers, fungicides, herbicides and insecticides. The income of the extension worker depends on the amount of chemicals sold.

introduced in Chancay-Lambayeque after the turnover in 1992. The history shows also the continuity of conflicts over water and institutional arrangements like the two types of water rights (permanent and excess water rights) and the arrangements for cleaning canals.

The infrastructure used to capture and distribute water has changed fairly little. Only the main intake works and main canals were improved and reservoirs and flow measurement structures were built in the last decades. Inside the secondary and tertiary canals undershot sliding gates were installed by the *haciendas* to allow a flexible control over the water distribution. These are still in use, although the governance and organisation of the systems has changed considerably.

Five main production systems were distinguished. (1) Rice growing by smallholders. (2) Rice growing by large landowners, that posses own land. (3) Entrepreneurs who grow rice on leased land. (4) Maize and bean growing by smallholders. (5) Sugarcane growing by co-operatives. The rice growing is characterised by high inputs and high outputs. Many smallholders and middle sized holders depend on money lenders or rice mills (*molinos*) for credit. This dependency often leads to coerced use of seeds and agro-chemicals, leading to further indebtedness.

3. Scheme layout, water use, and organisation of the two irrigation systems

3.1 Introduction

This chapter provides a detailed description of the three important parts that constitute an irrigation system: the irrigation infrastructure, the water and land use, and the organisation of the irrigation system. The chapter aims to give the reader the necessary overall understanding of the Chancay-Lambayeque and Jequetepeque irrigation systems to be able to understand the more specific descriptions on volumetric water allocation, scheduling, delivery and charging offered in Chapters 4 to 7.

The description of the organisation of the Irrigation Districts, both the internal organisation of the different tiers of the water users' association, as well as the three local government offices will be discussed. As explained in Chapter 1, the power relations and rules used in governance and daily management of the systems will be illustrated by looking at disputes and conflicts. Conflicts on allocation, scheduling, delivery and charging fees will be dealt with in Chapters 4, 5 and 6. Some examples of conflict management will already get attention here to help understand the relations between the different parts of the irrigation organisation.

The data presented in this chapter was mainly gathered by interviewing key informants at all levels of the water users' organisation and local government organisations. It was complemented by studying literature and archive material.

3.2 Infrastructure and scheme layout

3.2.1 Infrastructure and layout of the Chancay-Lambayeque irrigation scheme

Administratively the Chancay-Lambayeque irrigation system forms one 'Irrigation District' (*Distrito de Riego Regulado Chancay-Lambayeque*). As explained in Chapter 2, the Chancay-Lambayeque irrigation system has a long history. The infrastructure has developed in an 'organic' way. Since the building of the Taymi canal about AD 1000, the system has been expanded, changed, modified, modernised and reconstructed. This means that there is not one unique plan or 'designed' logic in the layout of the canals and design of the control structures. Rather, when new parts of the command area were put under irrigation the canals and division structures were constructed according to the initiatives and ideas of the people then in charge. A relatively big change was brought about by the German-financed Tinajones project.

The Tinajones project reshaped the Chancay-Lambayeque system and its water supply with the building of the reservoir in 1968, two tunnels transferring water from the Atlantic to the

Pacific side of the Andes: Chotano in 1960 and Conchano in 1983[1], and the lining of the main canal Taymi in 1968. However, the Tinajones project did not interfere in the secondary canals nor in the tertiary blocks, except for the tail-end area 'Valle Nuevo' (Urban 1990, IMAR 1997b). The Valle Nuevo is the most northern zone of the Chancay-Lambayeque system. It received very irregular supplies and had no water rights previous to the Tinajones project. Now this expanded area has the same rights and water supply compared to the older part of the system, even though it is still a tail-end area and suffers (and gains) more from fluctuations in river supply.

The Tinajones reservoir is an 'off-line' reservoir situated in the hills about 15 km upstream of the main intake works for the main canal Taymi. Its design capacity is 317 million m^3. The capacity is small in comparison with the average volume of water used during the irrigation season, which is about 900 million m^3. The main function of the reservoir is therefore not to store water over years, but to enable an early start of the irrigation season. This is mainly important for paddy, as temperatures set a tight period for growing rice. This forces the rice growers to start already in a period when the discharges in the river are normally still limited. The intake and offtake canal from and to the Chancay river have each a capacity of 70 m^3/s. No sedimentation problems have been reported for the Tinajones reservoir. With the heavy rains of the El Niño in 1998 the main earthen dyke of the reservoir was damaged and the effective capacity of the reservoir is now reduced to some 200 million m^3.

The main intake works for the main canal are called 'Repartidor La Puntilla'. A large concrete weir across the river heads up the water and the intake is regulated with four sliding gates. The bocatoma La Puntilla is situated at 125 m above sea level. The capacity of the first reach of the Taymi canal is 90 m^3/s. The 56 km of the Taymi canal and its extension the Heredia canal in Muy Finca are lined. The slope of the main canal Taymi is on average 0.002. Along the Taymi canal the secondary canals of different *Comisiones de Regantes* take off. The offtakes are regulated with radial or sliding gates in the offtakes. In the ongoing main canal there are only two water level regulators. In most cases the discharge of the offtaking canal can be measured with a Parshall flume. Besides the main '*bocatoma*' (or intake work) in the Chancay river, upstream of the La Puntilla *bocatoma* there are five small *bocatomas* with a total capacity of 15 m^3/s, and downstream in the Reque[2] river five minor canals also take water directly from the river with a total capacity of 9 m^3/s.

The irrigated area has grown from 60,000 ha in 1928 to 110,000 ha in 1994 (+40%). In Table 3.1 the growth is presented in more detail. Water availability only grew by about 24% because of the Chotano and Conchano tunnels.

Table 3.1: Growth of the Chancay-Lambayeque irrigation system in ha. (source: IMAR 1997b)

	1928	1964	1968	1994
Permanent water right	44,774	59,800	68,800	87,145
Right to excess water	14,866	n.d.	31,200	23,330
Total	**59,640**	**n.d.**	**80,000**	**110,475**

[1] The Chotano tunnel has a length of 4.8 km and a capacity of 31 m^3/s and the Conchano tunnel has a length of 4.2 km and a capacity of 13 m^3/s. The tunnels mainly supply water in the rainy season: on average together 226 million cubic metres per year.

[2] After the main intake of the Taymi canal the Chancay river is called Reque river.

Despite the 'organic' growth of the irrigation system the technology encountered today in the field is of an unexpected uniformity. The main type of division structure is the manually operated sliding gate, and to a lesser extent (and especially in the tertiary canals) wooden stop logs are used. In Chapter 5 the different configurations of division works will be analysed. Photos 3.1 and 3.2 show the type of sliding gates encountered most often. The older ones are quite robust, with hard-stone masonry, the new ones have a casting made out of iron. Most gates are in reasonable operational condition. The undershot gates allow for a great deal of flexibility in the distribution of water. However, this requires a tight control on the settings of the gates, and thus a control over the operators of the gates.

Photo 3.1: Old style sliding gate

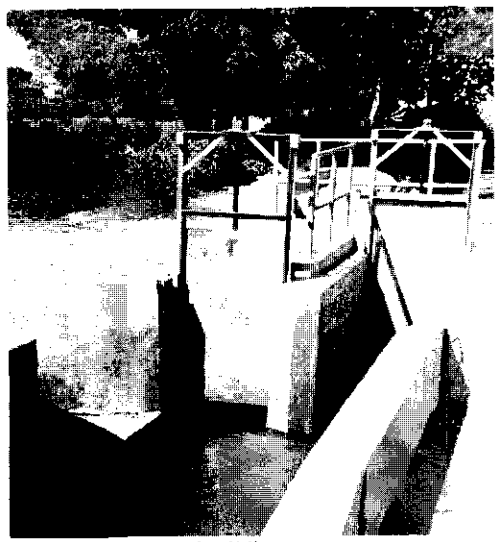

Photo 3.2: New style sliding gates

The layout of the canals is roughly a 'tree form'. They fan out on the right bank from the La Puntilla head works across the alluvial fan of the Chancay river. On the left bank only some small canals take water directly from the river (see Figure 3.1). The total water losses due to seepage in the unlined secondary and tertiary canals is estimated to be on average roughly 30 percent. Water losses tend to be higher in the head-end of the system, because of lighter soil texture, less saturation of the soil and lower groundwater tables.

In total 22,260 users had a water right (either a permanent or excess water right). The titleholders in the irrigation systems were mainly smallholders and middle sized landholders that derived their rights either through buying of land, or by the parcellation of the co-operatives in the 1980's. About half of the water users lived near their plot, the houses mostly grouped in small hamlets. The other half lived in the nearby towns of Chiclayo, Lambayeque, Ferreñafe, Túcume, Reque and Eten.

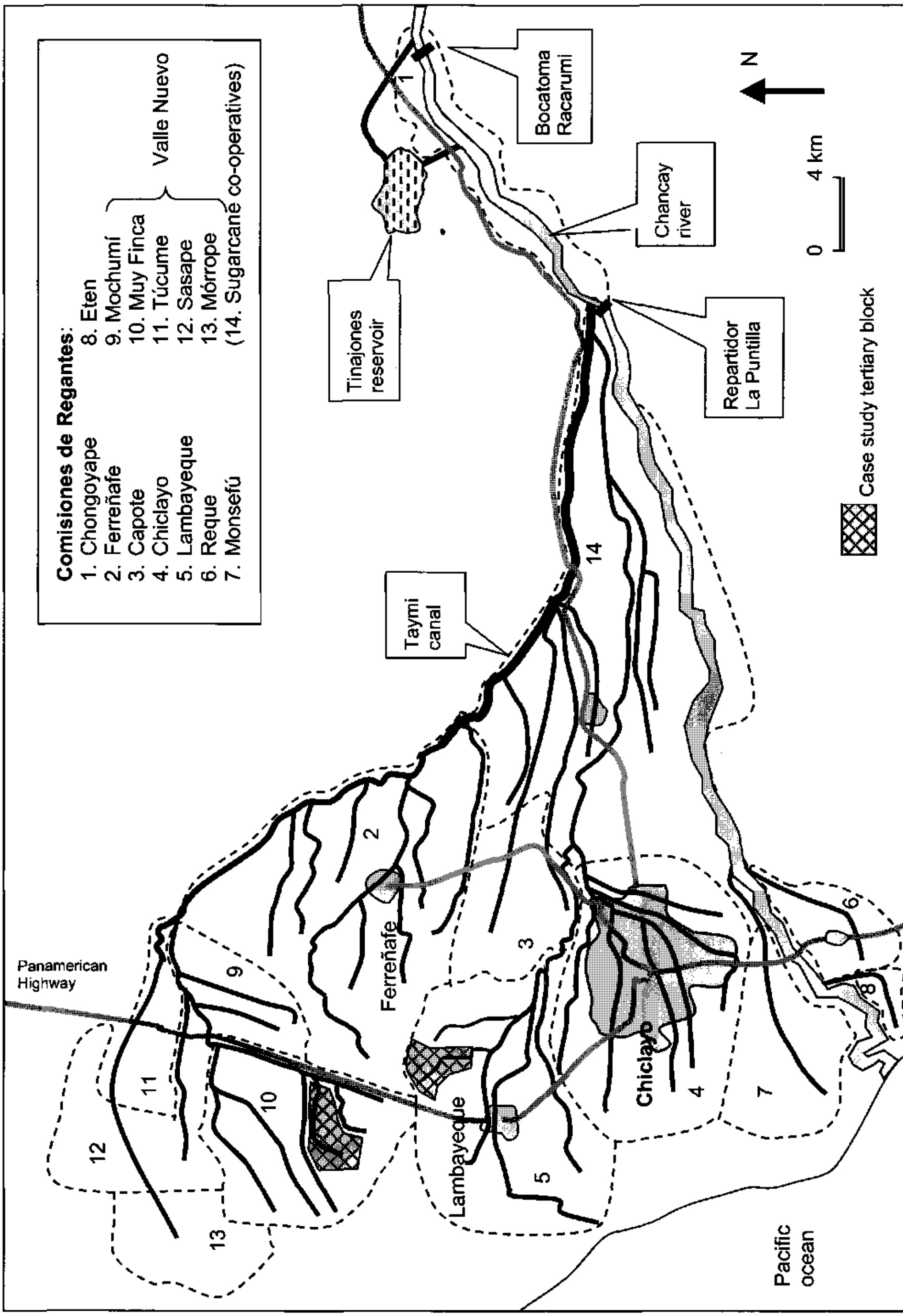

Figure 3.1: Map of Chancay-Lambayeque irrigation system

The command area was divided in 13 '*Subsectores de Riego*' in the middle and tail reaches of the irrigation system, and the area of the three sugarcane co-operatives in the head-end of the system (Figure 3.1 and Table 3.2). Each subsector had one or more secondary canals (some smaller subsectores took water directly from the river). Each subsector was managed by a *Comisión de Regantes*.

The drainage system was constructed only from 1970 onwards. In the thousands of years before, no specific canals for drainage had been constructed. Now in total eight main drains with an extension of 200 km have been dug and in most areas minor drains have been constructed with a length of about 220 km. As the drain system has been designed and constructed after the irrigation canal system it was difficult to locate the drains in a way they would not cross the irrigation canals. Most drains are crossed by irrigation canals at numerous places, by means of aqueducts made of concrete. This caused much damage with the El Niño floods, because the force of the floodwater tends to erode the banks of the drains, which makes the aqueducts collapse.

Table 3.2: Subsectores in Chancay-Lambayeque (Source: IMAR 1997b:Cuadro 27)

Zone	Subsector / *Comisión de Regantes*	Number of users	Area with permanent water right (ha)	Area with right to excess water (ha)	Total area (ha)
Above main intake	Chongoyape	1,714	6,814	5,087	11,901
Sugarcane co-operatives	-	3	25,476	0	25,476
Middle reach (Valle Viejo)	Ferreñafe	3,528	16,824	1,579	18,403
	Capote	488	2,501	1,813	4,314
	Lambayeque*	1,610	5,429	2,255	7,684
	Chiclayo	1,339	6,166	886	7,052
Tail end (Valle Viejo)	Monsefú	2,914	3,658	2,518	6,176
	Reque	550	758	434	1,192
	Eten	463	237	401	637
Tail-end (Valle Nuevo)	Mochumí	1,305	3,902	812	4,714
	Muy Finca*	1,979	7,793	2,415	10,208
	Túcume	727	1,519	291	1,809
	Sasape	1,432	3,248	1,516	4,764
	Mórrope	4,211	2,822	3,322	6,144
Total		**22,263**	**87,145**	**23,330**	**110,475**

* study sites

3.2.2 Infrastructure and layout of the Jequetepeque irrigation scheme

The Jequetepeque system forms an Irrigation District: *Distrito de Riego Regulado Jequetepeque*. The Jequetepeque irrigation system is also an ancient system, which also has grown, changed and adapted in an 'organic' manner. No tunnels have been constructed as in Chancay-Lambayeque. The Gallito Ciego reservoir, also built with German funds was put into use in 1987. It has a designed useful storage capacity of 400 million m^3. It is an 'in-river' reservoir, with consequent problems with sediment build-up. It is estimated that after the El Niño of 1998 between 58 (according to measurements of sediment load of the inflowing water) and 100 (according to bathymetric survey) million m^3 of sediments have entered the reservoir. This does not affect the useful storage capacity much, but could make the outlet of the dam useless in the near future.

The main intake Bocatoma Talambo Zaña ('Botaza') is situated some 16 km downstream of the dam. It is a concrete weir across the river and the intake into two canals on the right bank can be regulated with electrically powered sliding gates (Photo 3.4). The capacity of the intake is 86 m^3/s. This capacity is designed for the future execution of the complete Proyecto Especial Jequetepeque-Zaña. Currently, the served area of the Talambo canal is much smaller

(30,000 ha), for which the capacity of 86 m^3/s is much too high. This causes problems because no check structures were designed in the canal and with the relatively small flow currently released the water level is too low for the first offtakes. This has been solved by the *Comisión de Regantes* Talambo by building small temporary check structures in the reaches downstream of each of the offtakes.

Photo 3.3: 'Rustic' *bocatoma*

Photo 3.4: Main head work 'Botaza'

Besides the main Botaza intake, two larger and several smaller bocatomas take water from the Jequetepeque river. The two bigger ones are: Bocatoma San José-San Pedro (17 m^3/s) and Bocatoma Jequetepeque (2.6 m^3/s). These *bocatomes* are made of concrete, but do not have a permanent weir across the river. The intake is harder to regulate because the water level in the river can only be regulated somewhat by constructing temporary weirs out of stones. The most important smaller *bocatomas* are Tolon (1.5 m^3/s), Tecapa (1.8 m^3/s), Ñampol (0.6 m^3/s), Zapotal (0.3 m^3/s) and Huabal (1.2 m^3/s). As Eling (1987) explains, these *bocatomas* are sophisticated pieces of indigenous technology. They consist of a temporary weir in the river built from stones and tree trunks (see Photo 3.3). The advantage of the 'rustic' *bocatoma* is that it is built at low costs, it can be adapted easily to the ever changing position of the river and collapses without causing major damage.

As can be seen in Figure 3.2 the layout of the canals in Jequetepeque is also a 'tree structure'. The Botaza headworks are situated at 200 m above sea level. The slope of the Guadalupe canal is on average 0.004. Only the new Talambo main canal is lined. Water losses in the canals in the upper part of the scheme can be very high due to seepage. In the lower part of the system the canals may 'gain' water from inflow from groundwater during the second half of the irrigation season. For example the Guadalupe main canal will still be able to distribute water, in this period, even if the gate at the head-end is completely shut.

Some measurement structures have been built to measure the discharges in some secondary canals. The intakes along the new Talambo main canal all have measurement structures. The intake of the Limoncarro and Guadalupe canals have Parshall flumes. The division structures are sliding gates of the type shown in Photos 3.1 and 3.2. Most are in good operational condition.

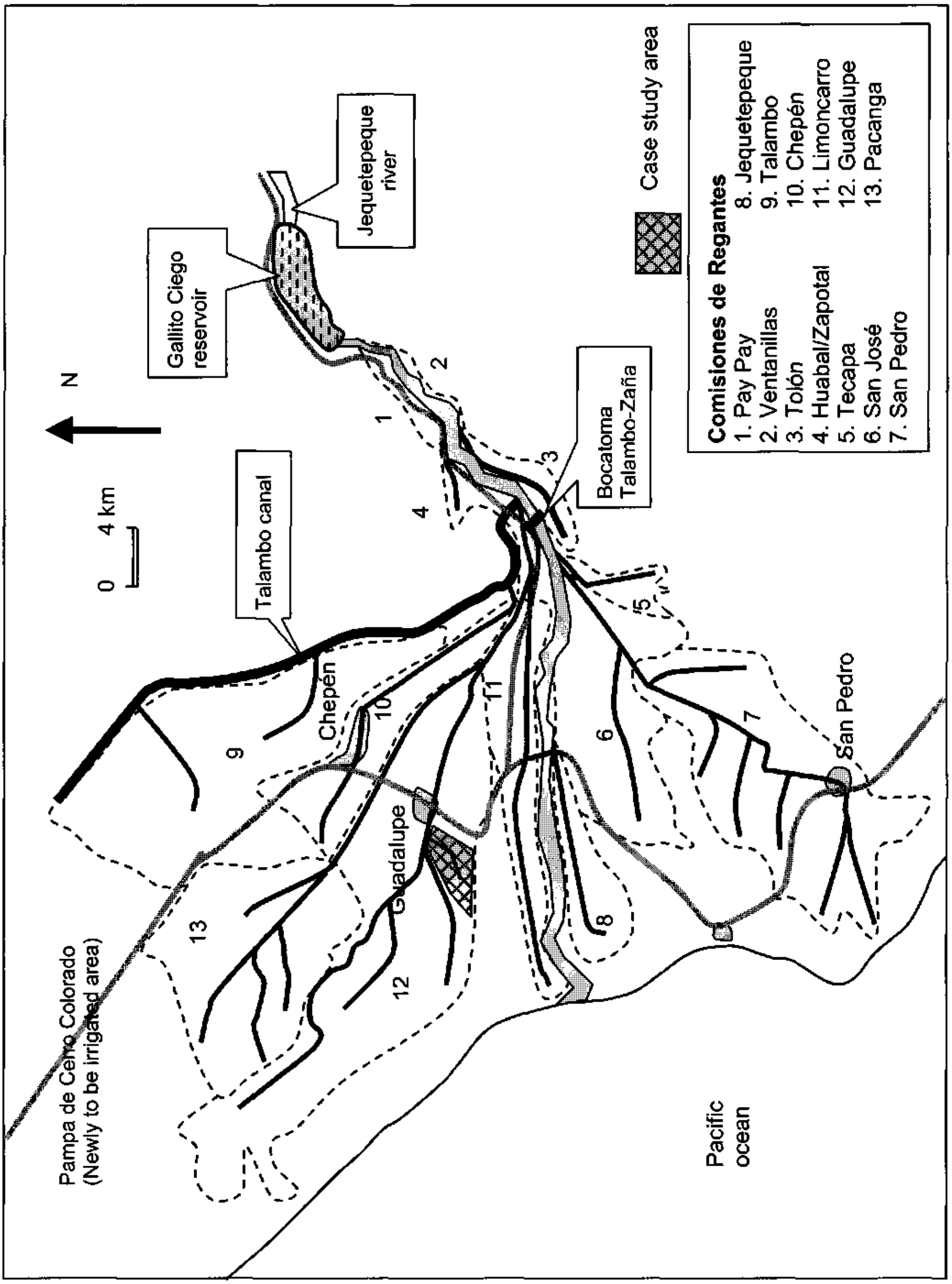

Figure 3.2: Map of Jequetepeque irrigation system (adapted from Carpio and Mejia 1996

The total command area of the Irrigation District (and system) is about 42,500 ha of which 32,500 ha has permanent water rights and 10,000 ha has only right to excess water. In total about 12,000 water users are registered (see Table 3.3). The water users live mostly in the small towns scattered throughout the command area: Chepén, Guadalupe, Jequetepeque, Pacanga, San Pedro and San José. Hardly any houses can be found among the fields in the irrigated areas themselves.

Table 3.3: Subsectores (or *Comisiones de Regantes*) in Jequetepeque (source: Carpio and Mejia 1996: Cuadro 4)

Zone	Subsector/ *Comisión de Regantes*	Number of users	Area with permanent water right (ha)	Area with right to excess water (ha)	Total area (ha)
Above main intake	Pay Pay	103	238	12	250
	Ventanillas	96	296	19	315
	Tolón	320	1,096	126	1,222
	Huabal/Zapotal	275	592	55	646
	Tecapa	523	966	147	1,113
Left bank: Head-end	San José	980	2,832	727	3,558
Tail-end	San Pedro	1,670	3,928	697	4,625
	Jequetepeque	369	1,240	147	1,387
Right bank: Head-end	Talambo	2,250	4,596	4,041	8,637
	Chepén	730	2,970	3	2,973
	Limoncarro	1,288	3,365	109	3,474
Middle reach	Guadalupe*	2,285	8,176	1,382	9,558
Tail-end	Pacanga	1,044	2,227	2,585	4,811
Total		**11,933**	**32,522**	**10,049**	**42,571**

* study site

Some 200 km of drains have been constructed in 1990. Fewer aqueducts had to be constructed to pass the irrigation canals (compared to Chancay-Lambayeque), because the drains are situated more on the limits of the irrigated area.

3.3 Water and land use

3.3.1 General cropping pattern in time and space

The main crops in Chancay-Lambayeque and Jequetepeque are rice, sugarcane, maize and beans. To a lesser extent a larger diversity of crops is grown like cotton, vegetables and fodder crops. Table 3.4 indicates the cultivated areas of the main crops. The area cultivated with rice depends much on the availability of water. As sugarcane is a perennial crop its area cannot be adapted that easily: it is planted for six years and early up-rooting in a dry year would mean an economic loss.

There are two main cropping seasons: the main irrigation season in summer when rice is grown, from October to May. This coincides with the increased discharges in the rivers as shown in section 2.2. In a wet year the cropping intensity (c.i.) is almost 100% in the rice and sugarcane areas during the main irrigation season. The complementary irrigation season, in winter, when maize and beans are grown, is from May to October.

In Chancay-Lambayeque the farmers are only allowed to grow one of these crops a year: either rice or maize. Thus, those farmers have a fallow field in the other growing season. In Jequetepeque most water users are allowed in most years to first grow rice and then maize. In the head-end of Jequetepeque even rice may be grown as second crop after the first rice crop.

In dry years the rice plots are not cultivated (or only partly) during the main season, but might be cultivated with maize starting from April. Decision-making on cropping is analysed in Chapter 4.

Table 3.4: Cropping pattern according to the official statistics in the main irrigation season in a wet and a dry year in Chancay-Lambayeque and Jequetepeque

	Chancay-Lambayeque[1]		Jequetepeque[2]	
Area (in ha.)	Wet year (1993-94)	Dry year (1991-92)	Wet year (1993-94)	Dry year (1991-92)
Sugarcane	30,000	28,000	1,500	500
Rice	38,000	15,500	24,500	19,000
Maize	9,000	9,500	9,000	7,000
Other	17,000	11,000	4,500	3,500
Total cropped area	94,000	64,000	39,500	30,000

1. Source for Chancay-Lambayeque: IMAR 1997b
2. Source for Jequetepeque: Carpio and Mejia 1996

In practice, in both Chancay-Lambayeque and Jequetepeque about 50% of the rice farmers grow a second crop after the harvest of their rice. This second crop is maize, sometimes associated with beans. Because the growing of a second crop is not officially allowed (in almost all years) they cannot claim water for this second crop. They take the risk of having to grow the second crop with only the water available in the ground after the rice season. However, in most years one or two irrigation turns can be given to the second crop. In total the c.i. in Chancay-Lambayeque in a wet year for the total command area would be about 1.1. This is more than 0.9, which is the official figure that does not take the second maize crop into account. In a dry year the c.i. is 0.7 (in a dry year the official data come more close to the reality). In Jequetepeque the c.i. is about 1.3 in a wet year and 0.7 in a dry year. Thus, in a dry year not all land with a permanent right is cropped. This is explained in section 4.3.2.

A special problem for the rice cultivation is the temperature. The minimum temperature should not be below 15°C. In the research area, the period when temperatures will normally not drop below 15°C is December to April. However, in some years December is still too cold and in other years low night temperatures already start in April. Low temperatures at the beginning of the rice growing season are not a problem for the production, but make the growth of the seedlings slower. This makes the total growing period longer and thus causes a higher consumption of irrigation water (a longer period with standing water in rice field). Temperatures below 15°C during the forming of the grains cause reduction of the yield (Grist 1986). The farmers are aware of this, and their strategy is to start cultivation of rice as early as possible. For example in Jequetepeque, in some areas rice nurseries are prepared in October. The *Comisiones de Regantes* try to prevent this because it causes increased water consumption and river flows are still small in October.

Sugarcane is mainly grown on land of the sugarcane co-operatives in the head-end area of Chancay-Lambayeque. Sugar used to be the main export commodity in the valleys, but since the world market prices have dropped and the management of the co-operatives is facing severe problems, sugar production has fallen dramatically.

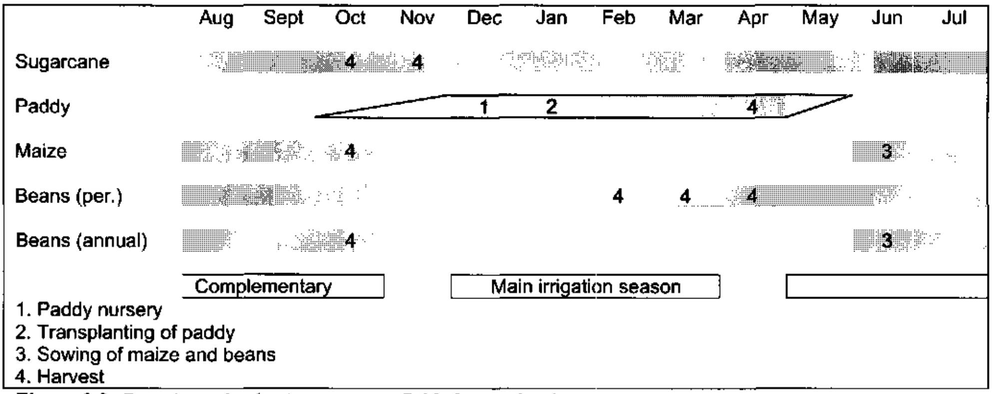

Figure 3.3: Cropping calendar (source: own field observations)

The spatial division of the cropping patterns is quite clear: in the head-end there is sugarcane (c.i. 80%). In the middle reaches there is rice in the main season (c.i. 90%) and maize and beans in the dry season (c.i. 50%). In the tail-end areas the cropping seasons are not so clear. Most tail-enders cultivate one crop a year (c.i. between 20 and 80%, depending much on water availability). This can be maize and/or beans. Also some cotton, fruit trees, pasture, and perennial beans are cultivated. Near the river there is intensive vegetable production.

3.3.2 Volumes of water used in both system

Users in Chancay-Lambayeque (who pay per volume) use half the amount of water in comparison with the amount of water used by the farmers of Jequetepeque (who pay unrelated to actual volume used) per hectare of crop type. In Table 3.5 some data to compare water use are presented. The data are calculated from water deliveries to areas with more or less the same crop. The data were cross-checked from different sources, field observations and actual flow measurements, and proved to give a good indication. The water use per hectare in both systems, as presented in Table 3.5, is somewhat lower in reality, because the actual cropped areas are bigger than the official cropped areas. In Chancay-Lambayeque farmers also grow crops on land without permission to grow a crop (this permission is called a PCR, see Chapter 4). They irrigate these crops with water requested for land that does have a water right. In Jequetepeque farmers have to pay per hectare, thus they tend to register officially less area than actually cropped (as water in normal years is sufficiently available to irrigate the complete land anyway). The illegal extension of the area, including drain water re-use is estimated to be about 20%.

From the table it becomes clear that farmers in Chancay-Lambayeque apply less water to the crops than the calculated crop water requirements (ETc). This can have a negative impact on the production. The low volume of water per hectare applied to rice (on average 9,500 m^3/ha in Chancay-Lambayeque in a wet year) is remarkable, because the percolation losses are not included in de FAO-CROPWAT calculations. This means that either the percolation from the field is very low or that the rice is suffering severe water stress. In field observations it was noticed that rice fields in Chancay-Lambayeque often are not longer submerged some days after a water gift. This does not always mean reduction in yield as intermittent irrigation is now even promoted for rice production, but it increases the amount of weed growth.

Table 3.5: Water use per hectare (m^3/ha), including conveyance, distribution and application losses

		Chancay-Lambayeque [1]							Jequetepeque [2]						
		Plot level (m3/ha)			Conveyance efficiency		System level		Plot level (m3/ha)			Conveyance efficiency		System level	
		(a)	(b)	(c)	(e)	(f)	(g)	(h) =c/f*g	(i)	(k)	(L)	(m)	(n)	(o)	(p) =L/n*o
River water availability		Etc	*Módulo*	Applied	Official	Measured	Cropped area (ha)	Water used (million m^3)	ETc	*Módulo*	Applied	Official	Measured	Cropped area (ha)	Water used (million m^3)
	Sugarcane	15000	20000	9500	75%	70%	28000	364	15000	20000	19000	75%	70%	500	12
Dry year	Rice	7800	14000	7200	75%	70%	15500	145	7800	15000	11500	75%	70%	19000	284
1991-92	Maize	4000	7100	3000	75%	70%	9500	37	4000	7100	6500	75%	70%	7000	59
	Other	3400	4200	2800	75%	70%	11000	40	3400	4200	6000	75%	70%	3500	27
	Total						**64000**	**568**						**30000**	**383**
	Sugarcane	15000	20000	13000	75%	70%	30000	507	15000	20000	28500	75%	70%	1500	56
Wet year	Rice	7800	14000	9500	75%	70%	38000	469	7800	15000	20000	75%	70%	24500	637
1993-94	Maize	4000	7100	3600	75%	70%	9000	42	4000	7100	8000	75%	70%	9000	94
	Other	3400	4200	2900	75%	70%	17000	64	3400	4200	7000	75%	70%	4500	41
	Total						**94000**	**1083**						**39500**	**827**

1. Source: IMAR 1997a (Cuadro N° 25, Anexo 4)
2. Source: INADE 1998 (Cuadro N° 30 and Balance Hídricos)
3. In the irrigation season 1993-94 the total release from the Chancay-Lambayeque river was 1,381.6 million m^3. From this 200 million m^3 was lost in the ocean and 63.3 million m^3 was used for industry and drinking water.
4. In the irrigation season 1993-94 the total release from the Jequetepeque river was 1,416 million m^3. From this 558 million m^3 was lost in the ocean.

(a) and (i): Theoretical crop water requirements are calculated with the FAO cropwat program (Version 7.0) based on FAO 1984, these are only rough indications, average climate date were used, no percolation losses were included (also not for rice).
(b) and (k): The *módulo* is the official volume of water assigned at field level to a certain crop per year per hectare by the local irrigation office of the Ministry of Agriculture (ATDR). Most stakeholders agree that the official *módulos* are more than actually needed at field level.
(c) and (L): The volume of water applied at field level. These are rough estimations derived from the total amount of water taken in by the complete system (measured and reported by the Junta de Usuarios) and the total areas of the different crops grown (data provided by the *Junta* and checked in the field) and the measured water losses (see (f) and (n)).
(e) and (m): Official losses due to seepage are fixed at 25% in Chancay-Lambayeque, in Jequetepeque the percentages are different for each *Comisión de Regantes* and change during the irrigation season and is even altered over the years. The 75% for Jequetepeque thus is not a very 'hard' figure.
(f) and (n): The measured seepage losses are on average 30% in both systems. This is a very rough estimation. Seepage losses differ widely between areas and throughout the irrigation season.
(g) and (o): For this calculations the cropped area is used as reported by the *Junta de Usuarios*. However, in reality more land is cultivated. It is estimated that in both systems about 20% of land is cultivated unofficially. This land is not used in this calculations because it does not influence the comparison. However, it does influence the productivity of water: by illegal re-use of the water the productivity of the water is increased, but not by 20% because the production in the illegal areas is quite low.
(h) and (p): The total consumed volume of water in both systems is the measured volume taken from the river. This volume is regarded as reasonably accurate. Because of all the rough estimations the water use per crop type might be different in reality. Hence, sugarcane might in reality use less, and rice more water, this is hard to estimate more precisely. Also losses might be higher and field applications lower. However, the overall picture of the comparison between the systems and the dry and wet year give good indications of the differences in water use.

The reduced water use in Chancay-Lambayeque does have effect on the yield. In Chancay-Lambayeque the average yield is about six tonnes of rice per hectare, compared to over eight tonnes rice per hectare in Jequetepeque. However, because in Chancay-Lambayeque they use only half the volume of water, the productivity per unit of water is still higher in Chancay-Lambayeque: 0.56 kg rice per cubic metre of water compared to 0.37 kg rice per cubic metre in Jequetepeque (see also section 7.4.1.).

Table 3.5 shows aggregated data, which do not explain the mechanisms at work. Therefore, in Chapters 4 to 7 we take a closer look at the complex relations between river discharges, water rights, water use and volumetric charging.

3.3.3 Salinity problems

Alva *et al.* (1976) investigated the salinity problems in the coastal valleys of Peru. They conclude that waterlogging due to lack of drainage causes considerable salinity in the lower parts of the valleys. The irrigation water itself is of good quality[3]. Also lack of irrigation water causes salinity. They estimate that in total 34 percent (255,000 ha) of the coastal agricultural land is affected by salinity to different degrees. The waterlogging is mainly caused by the high irrigation applications given to rice and sugarcane to maintain soil moisture (and a standing water layer for rice to reduce weed growth) for high yields. Little leaching happens during the irrigation of cotton, maize and beans. However, it are exactly these latter crops that are affected by the waterlogging. Under rice, salinity effects are repressed by the water layer on the field. In effect the farmers reduce the salinity by leaching the salts to deeper parts of the soils, but the salts are not eliminated from the soil profile. After the irrigation season the salts come to the surface again by capillary rise. If a farmer does not cultivate and irrigate the land for one or two years the surface of the soil is completely saline and cannot be cultivated anymore. In practice, one can see farmers scrap off the upper 5 cm of soil, completely white from salts, to the border of the plot before the first irrigation turn.

Farmers do recognise the salinity problem. They refer to saline soils as being '*fuerte*' (literally meaning 'strong', but more in the sense of 'hard to cultivate'). The waterlogging problem is also recognised: the maize and bean farmers are aware that paddy growing on neighbouring fields produces too much humidity in their maize and bean fields. One farmer expressed the problem in this paradoxical way: "*Too much water makes the plants dry*". What they, consequently, do is even reduce the irrigation gifts to the maize and bean fields, which can make the salinity worse.

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[3] In Chancay-Lambayeque the Electric Conductivity (EC) of twenty irrigation water samples was between 0.3 and 0.5 dS/m at 25 °C (measured in October 1998 and March 1999: GFA-Tinajones 1999). This is considered 'good quality' water by standards set by FAO (Rhoades *et al.* 1992). The EC of 35 sample fields throughout the command area was between 0.5 and 20 dS/m, most of the soils were between 1 and 3 dS/m. (GFA-Tinajones 1999). For soils the threshold value depends on the crop: rice yield is affected with EC of above 2.0 and maize yield with a EC above 1.1 dS/m (Southorn 1997). In about 10 percent of the rice fields damage to the crop because of salinity could be observed visually (patches of several square metres with badly affected plants). The EC of drainage water was found to be between 2 and 9 dS/m measured at 40 points in the major drains in Chancay-Lambayeque in November 1998. In Jequetepeque samples of the irrigation water showed also reasonable quality for irrigation: out of 15 samples taken, 12 had EC values below 1.5 dS/m indicating good quality irrigation water. The samples with higher values had increased salt contents because of drainage water flowing back into the irrigation canals. The sample of five plots had an EC between 0.6 and 2.5 dS/m. Drainage water had an EC of 2.5 dS/m on average, with a range between 1.2 and 5.9 dS/m (n=23). (GFA-Jequetepeque 1999)

The problem of paddy plots neighbouring maize and bean plots is recognised not only by the farmers, but also by the *Comisiones de Regantes* and the local irrigation office (ATDR). Together they try to plan zones for rice and zones for the other crops. The problem with this zonification is that the maize and bean farmers on the borders of the zones still have the negative effects from rice. They claim water to grow rice to be able to leach their fields. This is allowed in wet years, but once they have the right (PCR) to grow rice they will grow rice in the next years because rice is the preferred crop to grow. In this way the rice-zone increases each year until a very dry year in which there is no water for this expanded rice area.

As can be seen from Table 3.6 the salinity in Chancay-Lambayeque is increasing. With the construction of the main collector drains between 1969 and 1973 the area affected decreased somewhat. However, the positive effect was not sustainable. Similar developments have occurred in Jequetepeque, although, extension of saline areas has not been monitored. Three main problems contribute to the diminishing effect of the drains. First is the lack of maintenance of the drains. It was not completely clear who was responsible for the maintenance of the drains. This problem has been solved and the *Junta de Usuarios* now executes a large rehabilitation program for the main drainage system. Second is the filling up of smaller drains. Farmers rather fill up a drain to gain some land to cultivate, than to maintain the field drains in the tertiary blocks. Third is the increased growing of paddy.

Table 3.6: Indication of development of areas affected by salinity in Chancay-Lambayeque, in hectares (source: IMAR 1997b)

Year	1963	1968	1975	1980	1990
Head-end	2,100	2,700	9,100	6,500	2,100
Middle reach	8,500	16,800	22,200	21,500	30,300
Tail-end	3,500	4,100	10,700	3,800	7,800
Total	**14,100**	**23,800**	**42,000**	**31,800**	**40,200**

The low organic matter content and the sodicity[4] create a dispersed soil, i.e. its aggregation is lost. A little wind on an uncultivated piece of land rapidly causes large amounts of dust being blown into the air.

In conclusion, one can say that salinity is a major threat to large parts of agricultural land both in Chancay-Lambayeque and Jequetepeque. In Chancay-Lambayeque there is a combined effect of waterlogging and deficit irrigation of maize and beans. In Jequetepeque the problem is waterlogging in the lower parts due to poor drainage.

3.4 Governance and management by the water users' associations

After having presented the infrastructure and layout of the canal system, and shown the land and water use in the system, we now turn to the organisation of the irrigation systems. Actually the organisation is done by many 'sub-organisations' at different levels. These 'sub-

[4] Of 33 soil samples taken from fields throughout the Chancay-Lambayeque irrigation system, the Exchangeable Sodium Percentage (ESP) of 4 fields was above the threshold value of 15 percent, this indicates severe soil degradation, and almost all samples had a ESP of above 8 percent which is considered by some experts to be also quite high (GFA-Tinajones 1999). In Jequetepeque the ESP values are much lower: in the range of 2 to 6 percent (GFA-Jequetepeque 1999).

organisations' are different of nature: some are water users' associations, others are private companies and others are government organisations. In the next sections the structure of the organisations will be analysed presenting the domains in which each part of the organisation is active. As explained in Chapter 1, a useful way of exploring the rules used, the power and accountability relations within and between complex organisations, is to look at conflicts. Therefore, in the following analyses conflicts and conflict management will get special attention. However, a complete analysis of conflict management is only useful after having presented the organisation of water allocation, scheduling, delivery and charging (Chapters 4, 5 and 6). Therefore, conflict management is further analysed in Chapter 7.

3.4.1 The three tiers of the water users' organisation and the local government offices

All small and large-scale irrigation systems on the coast of Peru are managed by *Comisiones de Regantes* (CR) and their federations: *Junta de Usuarios* (JU). In large-scale systems the *Comisiones de Regantes* manage the secondary canals and the *Junta de Usuarios* manage the main infrastructure. The *Comisiones* and *Juntas* are financially autonomous and are responsible for the Operation and Maintenance (O&M). At the level of the tertiary blocks *Comités de Canal* (CC) are active, be it officially recognised by the government or not. It is important to distinguish between the elected board and the staff it employs. Although the *Comisiones* and *Juntas* took over the management in the period from 1989 to 1998, currently several local governmental organisations are still important in water management: the *Administración Técnica de Distrito de Riego* (ATDR), the *Autoridad Autónoma de la Cuenca Hidrográfica* (AACH) and the Special Projects Bureaus.

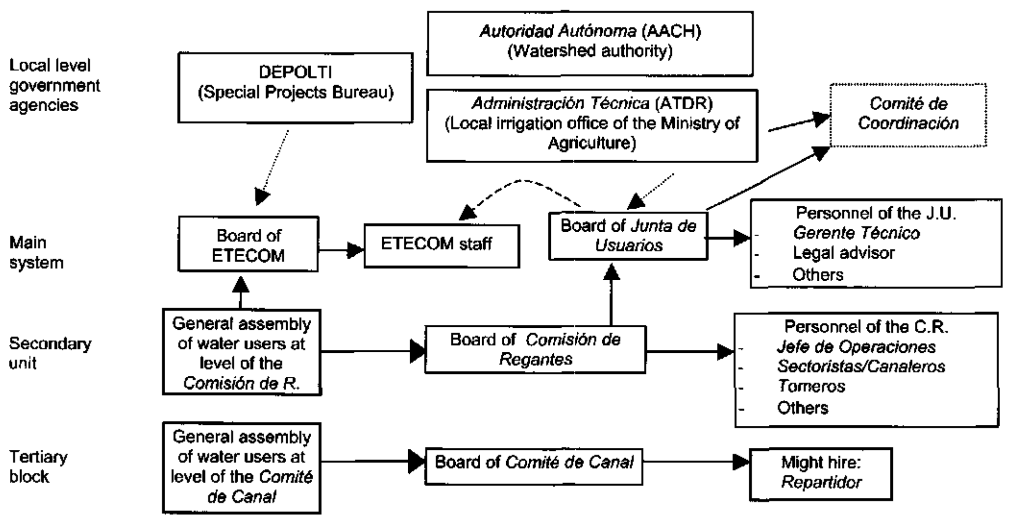

Figure 3.4: Organisation chart of the different layers of the water users' organisations and the three local government offices in Chancay-Lambayeque (source: own data)

Figure 3.4 shows a simplified configuration of the structure of the different levels of water users' organisations, the private company and the government offices. The groups of actors with their domains, and lines of accountability will be described below. The order chosen to present the groups of actors is from below to above. We start with the water users and the *Comité de Canals* at tertiary level and travel up in the hierarchy to the governmental organisations. In this way we can follow some of the conflicts that travel up in the hierarchy of organisations.

3.4.2 Individual water users

In figure 3.4 the individual water user is not present as such. It is the general assembly of all water users at the level of the tertiary block, which can elect a board of directors of the *Comité de Canal*. The general assembly at level of the secondary canal chooses a board of directors of the *Comisión de Regantes* and the board of directors of the private company (ETECOM in Chancay-Lambayeque). The *Junta de Usuarios* is not chosen directly by the water users. The *Junta de Usuarios* consists of the *presidentes* and two delegates of each *Comisión de Regantes*.

Not all *de facto* water users have an official vote in these general assemblies. Four conditions determine a *de jure* water user: registration in the *padron de usuarios* (the list of titleholders managed by local irrigation office of the Ministry of Agriculture, ATDR); having a *licencia* water title; the water user has to make use of the water him or herself; and the users should not have debts with the *Comisión de Regantes* nor *Junta de Usuarios*.

According to State law (decree 037-89-AG) there should be organised elections for the board of directors of the *Comisión de Regantes* once every two years. However, the Fujimori Administration had cancelled by decree these elections three times in a row. Thus by the end of 2000 in Chancay-Lambayeque the same board had been in place for eight years. In Jequetepeque the same members had been in place for six years. This increased the intensity and amount of conflicts between the water users, the board of directors of the *Comisión de Regantes* and the *Junta de Usuarios*. Officially, each *de jure* water user has one vote in elections of the board and one vote in the general assemblies[5].

In practice it is not so clear who the 'real' water user is. In many cases it is not the person registered in the *padron de usuarios* who is actually cultivating the plot. Often it is a family member of the official titleholder who is farming the plot and goes to the meetings of the *Comisión de Regantes* and *Comité de Canal*. In other cases the land and water title has been sold, or the land is divided among the heirs, but the title has not yet been changed in the *padron de usuarios*. In case of land leasing the owner is normally seen as the person entitled to vote. This situation occurs frequently. The community of irrigators, however, knows who is farming which plot and there is a high degree of social control: a water title can unofficially be passed on to a relative, buyer, heir or sharecropper, but the community will only accept one vote. In some cases the water user might have a debt, but is nevertheless regarded as entitled to vote. The fact that *permiso* titleholders are not considered water users according to the law, does in practice not exclude many users. This is because most *permiso*-holders also

[5] In August 2000 this was changed by decree 047-2000-AG (later replaced by the slightly modified 057-2000-AG). This degree modified the 037-89-AG decree, on the regulation of the *Comisiones de Regantes*. In the new regulations the weight of a vote in the general assembly is bigger according to landholding. This change was introduced to safeguard the interests of the new big landowners in the new irrigation systems like Chavimochic.

have a *licencia* plot. Truly 'illegal' water users are those farmers stealing water from canals or using returnflow water from the drains. The relative number of these illegal users is small and they have no say in the *Comisión de Regantes*.
Most water titles are in the name of the male head of the household, only 12% of the water titles are registered in the name of a female water user. This can be a widow or a (mostly married) woman who has inherited a piece of land from her parents (Huber 1990 reports that although sons and daughters are supposed to inherit the same amount of land, in practice half of the daughters did not inherit any land). Very few water titles are registered on the name of both spouses (Kome 1998). In practice the vote in the general assembly can be cast by any member of the household as long as only one representative is put forward.

Besides elections, the general assembly has another way to influence the management by the board of directors of the *Comisión de Regantes*. Decree 037-89-AG states that the general assembly should approve the work plan and budget for the coming year, and should approve the accounts at the end of the year. These two meetings every year are held in all *Comisiones de Regantes* in Chancay-Lambayeque and Jequetepeque. The meetings are important for both the board and water users, and the boards prepare the budgets and balances with great care (see Chapter 6). A meeting of the general assembly can also be organised if special issues have to be discussed and/or decisions have to be taken according to the board or the majority of the water users. Few such special meetings of the general assembly happened in Chancay-Lambayeque or Jequetepeque in the study period: on average one or two special meetings were held every year. In 1998 there were meetings in both systems on the protest to be organised against lack of government support for the rice farmers, and in Jequetepeque there were meetings about government plans to expand the irrigation system by selling desert land to a multinational.

Photo 3.5: General assembly in CR Lambayeque, on the right the board sits behind the desk and a female water user addresses the meeting (the two pictures were taken during the same meeting but do not show the complete meeting hall: there were more rows with water users than shown)

The attendance of water users during the general assemblies is rather low. It is estimated that in most meetings less than 30% of the water users attend the meeting (although the meeting places are crowded as can be seen in Photo 3.5). The actual participation in the debate or simply asking some questions is only done by three of four (male) water users. The others are just listening to the speeches of the directors of the *Comisión de Regantes*. Only seldom voting takes place. This suggests a low degree of participation, but as will be discussed below, the actual participation of the users in the management is bigger than can be seen from the participation in the general assembly meetings. Also the function of the general assembly meeting in informing the water users should not be underestimated[6]. After the meeting those who attended will inform other water users at their villages. In some *Comisiones* the attendance of the assembly is obligatory. But water users evade paying the US$ 3 or 6 fine by letting others sign the registration control list.

3.4.3 Comité de Canal

Comités de Canal (CC)[7] are water users' associations at the level of the tertiary blocks. The main task of the *Comités de Canal* is the organisation of the cleaning of the canals in their block. Furthermore, the *presidente* of *Comité de Canal* has the task to resolve minor disputes and conflicts among water users in the block. In special cases the *Comité de Canal* also organises the water distribution inside the tertiary block. The national water regulations only contain one article about the organisation of the tertiary blocks. In decree 0048-91-AG article 126 states: "*If the Comisiones de Regantes consider it necessary they can create Comités de Regantes to help them in canal cleaning and maintenance works and in special cases distribute the water according to the agreed rules*."

The actual organisations of the water users at the level of the tertiary blocks is in most cases not recognised officially by the governmental local irrigation office (ATDR). This is not to say that there are no organisations in these tertiary blocks: in informal ways there is always some sort of organisation to clean the canals and regulate the distribution of the water. The tertiary blocks that were selected for this research in Chancay-Lambayeque did have *Comités de Canal* that were officially recognised by the ATDR. The *Comités* in the selected areas in Jequetepeque were not recognised by the ATDR, but nevertheless the *Comisiones* did work with the informal organisations at tertiary level.

The number of *Comités de Canal* inside a Subsector tend to change from year to year. For example in Subsector (and thus *Comisión de Regantes*) Lambayeque in the irrigation system Chancay-Lambayeque there were 13 *Comités de Canal* in 1994 (each with on average 120 water user and 600 ha). In 1996 some *Comites* had split up and the total number of *Comités* was 16. There is a tendency in other Subsectores as well to split up *Comités*. However, the *Comités* still coincide with hydraulic boundaries of tertiary canals. The *Comités* that split up had previously more than one tertiary canal, or each new *Comité* takes one main branch of a tertiary canal as their new domain. The split up is mainly related to mistrust among the users.

The board of directors of the *Comisiones de Regantes* see the *Comités* as potentially troublesome, because they can undermine the authority of the *Comisión de Regantes*. However, although in most cases not officially recognised, the organisations of the water users in the tertiary blocks are very important for the water distribution and maintenance of the canals. Thus, the *Comisiones* rely on them for the maintenance, water distribution and conflict resolution.

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[6] See Musch (2001) for the importance of information in the process of participation.

[7] In many parts the *Comités de Canal* are known under other names like: '*Comité de Ramal*', '*El Ramal*', or referred to only by the farm leader called '*Delegado del Ramal*'. For purpose of readability I will use the term '*Comité de Canal*'.

The *Comités de Canal* have existed for a long period. In the time of the *haciendas* some sort of organisation at the tertiary canal level was used in an instrumental way to clean the canals. In areas outside the control of the *haciendas* (thus in the *Comunidades*) the *Comités de Canal* executed the O&M in the tertiary blocks. Normally they would appoint a '*caporal*' to allocate the cleaning assignments and to control the compliance of the assigned tasks. The job of *caporal* would rotate among the more respected male water users. Supervision over the water distribution would normally be done by another water user, also appointed by the water users in the tertiary block. These informal leaders also used to mobilise the required labour for cleaning of secondary and main canals.

After the land reform of 1969, and the IMT of begin 1990's, the role and functioning of the informal water users groups in the tertiary blocks did not change much. Only in some places the organisation became formally recognised by the ATDR. In these organisations, elections were held and a board of directors was elected. The board exists of a *presidente* and four other members.

The *Comités de Canal* did normally not have an office, the meetings were just somewhere in the field or in the house of the *presidente*. Some *Comités* hired a person to schedule, distribute and monitor the water inside the tertiary block. In Chancay-Lambayeque they called this person the *repartidor*. He was usually a son of a water user and was paid directly by the water users. They all paid a fee per hour of water requested. For the users this meant an extra service: they did not need to go to the office of the *Comisión* (1 to 10 km away) for consult on the scheduling and requesting and paying the water turns. Also the delivery would be better if a paid person monitored the distribution (see Chapter 5).

The canals in the tertiary block are cleaned twice a year. In August before the main irrigation season the canals are dry and all canals are cleaned and deepened to restore the original rectangular profile (see Photo 3.6). Often the canals become even deeper than the year before, probably because the farmers think they can convey more water to their fields if they make the canals deeper. This, however, causes problems because more water is needed to fill the canals and head-up the water to be able to irrigate the lands.

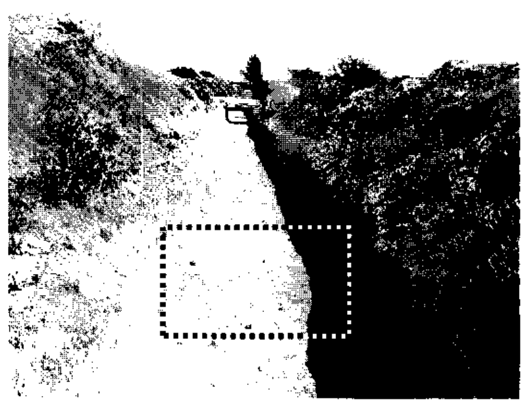


Photo 3.6: Recently cleaned tertiary canal in CC La Ladrillera, showing the typical rectangular shape of the canal cross section. The picture also shows the bunds of cleaned out sediments that have built up throughout many years

Somewhere in January the canals are cleaned of weeds. All cleaning is done by hand. Only simple tools are used like spades and sickles. All users in the tertiary block are assigned a section of the tertiary canal to clean. The size is proportional to the land holding. Some water users hire *peones* to do the cleaning which is assigned to them. The *presidente* of the *Comité* assigns a '*caporal*' to divide the work and monitor its progress. Each user that has finished her or his part gets a receipt that has to be handed over to the *Comisión* at requesting the next water turn.

Canal cleaning can suffer from free riding. Although the users agree on the need of cleaning of the canals many try to contribute as little as possible. The *Comisión de Regantes* has a simple rule: "No clean tertiary canal at the beginning of the irrigation season: no water to the tertiary canal". The rule is clear, but the practices are not so clear. The *Comisión* delegates the actual cleaning and organisation to the *Comités de Canal* (without bothering whether they are recognised officially or not). The *sectorista* (paid by the *Comisión de Regantes*) checks whether or not the canals of each tertiary block are cleaned sufficiently before anyone in that tertiary block can get the first irrigation turn. When the irrigation season starts it often happens that most water users did their duty, but one or two water users did not clean their part. This means that water can only flow freely up to the first section not being cleaned. In normal cases the *sectorista* will refuse to schedule any water to the tertiary block until the canal is completely cleaned. However, the *sectorista* can be put under great social pressure especially if the uncleaned sections are actually side-branches of the main tertiary canal, and the uncleaned parts do not obstruct the flow of water to the main part of the tertiary block.

A special case occurred in CC La Ladrillera in January 2000. A group of water users from that tertiary block requested the *sectorista* to no longer schedule water turns for the tertiary block. In this way they tried to enforce the rule of 'no cleaning no water.' Only one water user, the big landowner in the head-end had not cleaned his part of the canal, but nevertheless had been receiving water. The group of aggrieved water users also deprived themselves from water, but preferred that above the non-punishment of the big farmer.

The water users resolve many rule violations, disputes and conflicts among themselves. These cases mainly revolve around the following: the order of the water turns, water stealing, cleaning of canals, access to road or canals, or destroying of canals, drains and roads. The local social power relations among the water users influence the punishment of rule violation. Big farmers will get away with water stealing more easily than small farmers. However, the big farmer cannot just take any water (s)he wants. There is a sort of power balance in which also the bigger farmers have to behave within certain limits. The advantage of the resolution of rule violation among the water users themselves, is that all users have knowledge on the endogenous rules to be applied, the persons involved, and the actions taking place. For an outsider it takes much time to understand what actually is or was happening, who the involved parties are, what the history of the rule violation was, and what the exact rules are. It would be very costly if all these rule violations were resolved by higher authorities that have little knowledge and understanding of the local situation.

The *presidente* of the *Comité de Canal* in each tertiary block has the role to adjudicate when rule violations cannot be resolved among the users themselves. The *presidente* is a water user her or himself. This means that in most cases (s)he will have the local knowledge required to judge the situation. The *presidente* is chosen by the water users and will in most cases neither be a big or a very small farmer. The *presidente* is mostly male, but in some *Comités* the *presidente* is female. The election itself, the rules applied, and the resolution of rule violation, are informal. Nothing is written down. The sanctions applied are normally the payment of some small fine, mostly in a material form: for example two padlocks for a water theft.

As the *presidente* is a water user it can in some cases be difficult to be impartial. Many water users are relatives and often there is a certain level of friction between different parts within the tertiary block. This has two consequences. One is that the *presidente* in some cases is very hesitant to make a judgement. It is not nice to make enemies in your direct neighbourhood. The second is that one of the involved parties might consider the *presidente* too partial and connected to the opposite party, and will choose to complain to the *presidente* of the *Comisión de Regantes*.

3.4.4 Board of directors of the Comisiones de Regantes

The *Comisiones de Regantes* are the water users' organisations that manage the secondary canals. Their main tasks are water distribution in the secondary canals, maintenance of those canals, and conflict management. In both Chancay-Lambayeque and Jequetepeque there were 13 *Comisiones*. Their size varies, as can be seen in Tables 3.2 and 3.3, from 250 to 18,400 ha. All *Comisiones* had their own offices, situated in the major town or village in the command area of the secondary canals managed by the *Comisión*. Photos 3.7 to 3.9 give impressions of these offices: some are among the biggest and best buildings in town.

Photo 3.7: Office of the CR Lambayeque

Photo 3.8: Office of the CR Huabal-Zapotal

Photo 3.9: Office of the CR Pacanga

The board of directors of the *Comisión de Regantes* is elected by the members of the general assembly. The board is headed by the president (*presidente*) and has as members: the secretary (*secretario*), the treasurer (*tesorero*), the vice-president (*vice-presidente*) and two delegates (*vocales*). The members of the board do not get any salary. Only the *presidente* might receive a sort of daily allowance. Officially the board does not have tasks to occupy its members full time, but in practice most *presidentes* have a 'full time job' being *presidente*. As they are water users themselves they will have little time to manage their own landholding(s).

The rules and regulations the boards have to apply in managing the *Comisión* are laid out in general in decree DS 037-89-AG. This decree is quite clear on the governance structure, but leaves ample room for the boards to develop informal regulations for daily management issues. The *Comisiones* also have by-laws (*Estatutos*), some of which are very detailed, and regulate most important issues in the *Comisión*. These cover: the legal structure; the objectives and tasks of the *Comisión*; the tasks and organisation of the general assembly; the tasks and obligations of the board of directors and its members (including fines for non-compliance); elections of the board; tasks and obligations of the water users; the punishment of water users; financial affairs; and the organisation of the *Comités de Canal*.

The question then, of course, is to what extent these rules were applied in practice. Contrary to the initial expectations, most of the rules were applied quite strictly. The governance of the *Comisiones* is in practice almost exactly as prescribed in the Decree 037 and in the by-laws of the *Comisiones* (*Estatutos*). This is not to say that no mismanagement, conflicts, and offences occurred, but the line of authority, the tasks and obligation and the general conduct were guided pretty much according to the official rules. Still the by-laws leave some gaps in regulation of important activities of the *Comisión*. An example is the cleaning of the canals. The maintenance activities are crucial for the functioning of the irrigation systems, but are not regulated in detail in State law nor by-laws of the *Comisiones*. The cleaning of the canals is the responsibility of the *Junta de Usuarios* and *Comisiones de Regantes*, but how exactly they have to organise this activity is not described in the official regulations.

The cleaning of the tertiary canals is delegated to the *Comités de Canal*, this is done on the basis of customary rules. The maintenance of the secondary canals is done with machines according to the need perceived by both the board and the water users of the *Comisión*. There are no written rules on how, how often, and by whom, these canals should be cleaned. The customary rules applied and the practices, are however quite clear for the water users.

From all board members only the *presidente* is involved daily in the management of the *Comisión*. He or she (only in Jequetepeque one of the thirteen *presidentes* is a woman) has an office in the building of the *Comisión de Regantes*. The degree of daily involvement depends on the person who is elected *presidente*. In many cases the *presidente* runs the whole *Comisión*, in other cases the *presidente* takes the major decisions, but leaves the daily management to the staff. The *presidente* is normally a person with some experience in public functions. Some *presidentes* have been board members in production co-operatives. Other *presidentes* do not have much experience with management functions. Most *presidentes* are relatively well educated and some have studied at the local university. Most *presidentes* have ambitions in the sphere of local politics. In the municipality elections of September 1998 at least three *presidentes* were in the running for a post in the council.

The treasurer assists the bookkeeper or does the bookkeeping of the *Comisión* himself. The secretary writes the minutes and reads the minutes of the former meeting in the meeting of the general assembly. Other members of the board only have symbolic functions. Almost all members of the boards in Chancay-Lambayeque and Jequetepeque were male.

The board is in command to manage the secondary canals and the canals in the tertiary blocks. The board is responsible for: the planning, financing, execution and monitoring of the water scheduling; water delivery; maintenance of canals; structures; access roads and drains; construction works; communication with and training of the users; management of personnel; administration; and conflict resolution. The main problem for the boards is their lack of financial means to execute operation and maintenance (see Chapter 6). An example of the issues dealt with by the board of the *Comisión* is the buying of machinery for cleaning and repairing of canals. These require high capital investments, but could reduce the overall costs. Currently maintenance is mostly done by hand by the water users. For them it could be more profitable if they would have alternative employment during the canal cleaning. However, for most farmers it is more cost effective to work in the canal cleaning instead of paying for mechanised cleaning.

Maintenance, rehabilitation and construction of infrastructure is a daily issue at the *Comisión*. Users, individual and in groups, put forward requests for specific works to be done. They request repair of bridges, aqueducts and division structures. Also they might request realignment or construction of canals and division structures, to increase the water delivery to their fields. The board has a very limited budget for construction, but can try to raise funds with the Ministry of Agriculture or other organisation. The groups of users who benefits directly from the works are asked to pay a part of the costs. Nevertheless, few works are executed by the *Comisiones*. Extra funds from special projects like the PSI-World Bank rehabilitation project are used to rehabilitate the most important works.

The board (or in practice the *presidente*) has a strong position because it can appoint staff members. Unemployment is high and the jobs have several advantages (see below). Together with the power to allocate water to the farmers, this makes that the *presidente* is a resource broker. He or she can divide jobs and water, and settle conflicts. Vis-à-vis the water users the *presidente* has a sort of patron-client relation. But the 'patron' has no absolute power. The water users can vote for other candidates in elections, they can start also a court case with the charge of 'abuse of authority' at a civil court. The *presidente* is also accountable towards the ATDR.

Within the *Comisiones de Regantes* in Chancay-Lambayeque and Jequetepeque a constant struggle was observed between rival parties of water users. These groups were not clearly divided among lines of political parties, land holding, or other social groups. Alliances were more or less loosely grouped among kinship groups and spatial division according to irrigation canals. It was not so much differences in norms and values or different ideas on how to run the systems, but rather a struggle for power. They were political because they formed groups, formulated ideas on the management of the irrigation system, mobilized support from the users for these ideas, and finally they did this to gain power and control over the irrigation management. The meetings of the general assembly were important for the political factions in the *Comisión*, but also local newspapers and especially local radio stations were used to spread ideas and mobilise support. The faction that was not in power functioned like a 'watchdog' in the *Comisión* and also in the direction of the *Junta de Usuarios* and the company of the *Junta*.

Box 3.1 gives an impression of the content of a leaflet spread informally among the water users in Chancay-Lambayeque. The pressure put on the board by these sort of pamphlets and similar radio broadcasts should not be overestimated. Rumours on corruption and mis-management circulate constantly among the water users, but only very seldom lead to official accusations and filing of cases with the ATDR or a civil court. On the other hand, such informal accusations can undermine the authority of the boards and the boards will try to counteract the accusations to try to stay in place the next elections.

The conflicts appeared most clearly during the meetings of the General Assembly of the *Comisiones de Regantes* (see also section 6.2.3). The leaders of the opposition group or just individual water users would stand up and oppose ideas and proposals put forward by the sitting board. Normally the sitting board members just try to ignore the ideas and protests. In one case the board of the CR Guadalupe asked two local police officers to attend the General Assembly meeting on January 27^{th} 2000, because they feared a 'stubborn' water user would try to disturb the meeting. In the end the loud amplification and the monopoly of the board on the microphone proved to be sufficient to silence the rival.

In extreme cases the rival group could use a 'legal weapon'. This legal weapon is the law on 'abuse of authority'. Any member of an organisation can file a case against a member of the board of the organisation with the general accusation of abuse of authority. The police then have to investigate the case and will hear the accused person. A judge then adjudicates in a civil court case. One such case was started against the president of the CR Lambayeque in 1999. However the procedures take a long time and the police are mostly on the side of the sitting board members. This does not mean that the filing of a case of abuse of authority is without effect. It can damage the public image of the board member, depending on for example how the rival group presents the case in public.

Box 3.1: Opposition leaflet, December 1999

Examples of informal accusations published in an eight-pages leaflet spread by an opposition group among the water users in Chancay-Lambayeque:

- Corruption of the *presidentes* of the *Junta* and some *Comisiones*: they take 2% to finance a political organisation.
- The *presidente* of CR Chiclayo was proved guilty by civil court of taking away 33,000 Soles*, and the engineer of ATDR was also reprimanded because he knew about it, but did not take action.
- The *presidente* of CR Chongoyape was replaced by the water users because he could not justify the spending of 10,000 Soles acquired by the illegal selling of water.
- The spending of the ISF by the *Comisión* is wrong: too much goes to the travel, food and drinks of the board members, too little to the investments in the infrastructure of the irrigation system.
- The spending of the ISF by the ATDR and AACH is not transparent.
- One day after some water users started a court case against the *presidente* of CR Lambayeque on accusation of 'abuse of authority' the *presidente* went to the ATDR to denounce three offenders, upon which the ATDR immediately issued fines of 1,200 Soles each. This in itself is according to the law, but is clearly a reaction to the accusation because never before did the *presidente* and ATDR respond so quickly to infractions.

(signed by a water user from CR Lambayeque)
* 3 Soles = 1 US$

A more frequently used mechanism by water users to challenge the authority of the sitting board of the *Comisión de Regantes* is to complain to the ATDR. In case the ATDR considers the grievances serious, the ATDR might start an investigation that can lead to new elections for the board of the *Comisión*. The ATDR itself will not spontaneously initiate a process of substitution of boards, because its policy is maintain the status quo and stay at friendly terms with the sitting boards. In Jequetepeque some boards of the smaller *Comisiones* were replaced by newly elected boards, because the ATDR had judged the former boards to be insufficiently effective in collecting water fees. This action was however orchestrated by the *Junta de Usuarios*.

Conflicts can also focus on the functioning of an employee, for example the ditch rider (*sectorista*). Water users might accuse a *sectorista* of selling illegal water turns or giving extra water to certain water users. Usually the conflict between the water users who accuse the *sectorista* and the board of the *Comisión de Regantes* will be fought over among these two parties. Neither the *Junta de Usuarios* nor the ATDR will normally interfere as they see this as an internal affair of the *Comisión*. In this internal struggle the board of the *Comisión* will win in most cases. They can normally ignore the pressure of the water users and just carry on their practices (e.g. in CR Lambayeque the water users of secondary canal San José pressed for a substitution of the gate operator (*tomero*) of the upstream part of this canal: he was not replaced). Only in rare cases the water users can mobilise sufficient power to sack the *sectorista*. The water users can mobilise such power by involving the public opinion via the local newspaper and, more importantly, the local radio station. If the water users can mobilise sufficient public support, and for example organise an occupation of the office building of the *Comisión de Regantes*, the board is inclined to obey the wishes of the farmers to regain the public support (in view of the next elections of the board members).

In the two years of field study only one case of a successful action against a *sectorista* was observed: in CR Chiclayo. Another example of struggle over the competence of an employee is the case of the Chief Engineer of the *Junta de Usuarios* of Chancay-Lambayeque. In 1996 the General Assembly of CR Ferreñafe published an announcement in the local newspaper (see Box 3.2). In this announcement the assembly claimed to have lost 41 million soles (US$ 17 million) in agricultural production because the Chief Engineer from the *Junta* made a wrong decision regarding the start of the irrigation season. They demanded the immediate resignation of the Chief Engineer. The publication of the announcement did not lead to the desired result. The Chief Engineer was replaced only in 2000 after the elections of a new board of the *Comisiones* and *Junta de Usuarios*.

Box 3.2: Public announcement

COMISIÓN DE REGANTES DE FERREÑAFE

PUBLIC ANNOUNCEMENT

After noting the disastrous rice yields in the Subsector Ferreñafe, because of the erroneous management-decision to postpone the rice irrigation season 1995-96, in which, based on a pseudo prognosis of the river discharges (which proved to be never below average), the responsible actor: the wrongly-named CHIEF ENGINEER of the Junta de Usuarios, the engineer Miguel Ignasio, is the major cause of the debacle caused by the cold temperatures at the end of the season which negatively affected the rice production.

The culprit Miguel Ignasio, manipulated technical information on the prognosis based on statistics, that could not be treated this way scientifically to predict future river discharges and climate.

The postponement of the irrigation season in Ferreñafe caused a yield loss of 63.6%, which could be translated to 41,572,500 Soles, which us, the farmers, have to assume, without being those responsible. Because of this the GENERAL ASSEMBLY OF WATER USERS, on 18th of August of this year, in the Comisión de Regantes of Ferreñafe, has decided to ask for his resignation of the post he has fulfilled so deficiently, and thus this employee does, and will, not have our confidence, and also the engineer has been declared 'persona non grata' in the Subsector Ferreñafe.

We have published this announcement to alert all water users in the valley, to show that we will be watching our future and demand the immediate resignation of the responsible engineer.

The General Assembly — Ferreñafe, 26th of August 1996

(Source: La Industria, 30-08-1996, this is a locally widely read newspaper. The not-so-fluent English is a direct translation from the not-so-fluent original Spanish text, the name of the engineer is changed, 3 Soles = 1 US$)

It must be noted that the power struggles are not a consequence of differences in normative frameworks nor direct access to water (or water rights). The persons competing for power are driven by other reasons like: status (the position in the board of the *Comisión* might be a springboard to a political function); the money that can be made by illegal water selling and construction activities; and being in the position to assign preferential water rights to relatives. The laws and regulations referred to in this class of conflicts are the laws and regulations in the official State law. As the State laws are formulated quite generally it is the local interpretation by the ATDR or Judge of the civil court that counts. It is well known and accepted within the water users' association that the board members make illicit money out of illegal selling of water, the hiring of machines, the tender of construction contracts or misuse of subsidies on e.g. petrol. However, if an opposition group would bring those practices to court, the court might decide to punish the corrupt board member(s), depending on the available evidence.

3.4.5 Staff of the Comisiones de Regantes

All *Comisiones* hire employees. It depends on the size of the *Comisión* how many staff they need and can afford. Some small *Comisiones* have only an engineer (*Jefe de Operaciones*), a secretary and one *canalero* (ditch tender; in Chancay-Lambayeque called *sectoristas*). The bigger *Comisiones* employ: an engineer, a bookkeeper, a senior overseer, three to five *canaleros*, and a couple of *tomeros* (gate operators). The staff is hired directly by the Board of Directors of the *Comisión de Regantes*. Most of the people now working in the *Comisiones* have been working there at least five years, some even worked in the same job with the ATDR before the turnover. The salaries were low and most field personnel only got paid during the main irrigation season. Sometimes the salaries were not paid for several weeks, because the *Comisión* was behind schedule with the ISF collection. Still the employees tried to continue their work with the *Comisión* because there was very little alternative employment because of the economic crisis in Peru.

The engineer (*jefe de operaciones* or *coordinador técnico*) is the main person working with the *Comisión*. Although not all *jefes de operaciones* have a university degree they are addressed as 'engineers'. Actually in Jequetepeque the engineer is not employed by the *Comisión,* he is directly paid by, and accountable towards, the *Junta de Usuarios.* The engineer decides on major issues in the daily operation and maintenance of the secondary canals. Being *coordinador técnico* is a tough job. Many ad-hoc decisions have to be taken on a daily basis. Every day water users will line up in front of their small offices with a multitude of petitions, complaints, threats, and other issues that create tension and many issues need immediate action of some kind. He is in a powerful position because of his tasks of making decisions on water distribution, but that power is also limited by the fact that in most cases the president of the *Comisión* will take all major decisions. This brings the engineers regularly into difficulties. The *presidente* might make promises to different water users that are impossible to accomplish. For example, (s)he might promise water turns in times of scarcity, or promise the cleaning of canals with machinery that is not available. The engineer has to execute these directives. In Chancay-Lambayeque in general the *presidentes* choose engineers that are not too 'senior', so as to be able to control them better, and prevent a too independent stance. In Jequetepeque the engineers are hired by the *Junta* directly, which can cause frictions between the *presidente* and the engineer of the *Comisión*.

Besides the engineer two kind of jobs are important in the *Comisiones*: the *sectoristas* (or *canaleros*) and the *tomeros*. The *sectoristas* make the daily scheduling of the water, do water measurements and give instructions to the *tomeros* on changes in gate settings. The importance of the *sectoristas* will be highlighted in Chapter 5. The *tomeros* live near the gates, they execute the instructions of gate settings by the *sectoristas*, remove debris from the gates and register water levels. Apart from these formal functions they also provide vital information to both farmers and staff of the *Comisión.*

Besides the lack of opportunities for alternative employment, the staff members of the *Comisión* have two other reasons to work for the *Comisión* despite the low salaries. First of all the personnel feel proud to have a job with responsibility and respect from the users. Or as one *tomero* in Muy Finca put it: "*I have been working for the Comisión for twenty years now, I have much experience, at night-time I have to watch the gates here, if I fall asleep and a wave of water would overflow from the canal the whole village could flood. The engineer* [of the Comisión] *knows me and knows that I am a responsible person.*"

The other attractive aspect of being a worker with the *Comisión* is the opportunity to receive unofficial income from water users for special services. In a water scarce system as Chancay-Lambayeque water users are willing to pay for water delivered outside the official schedule. In a more water abundant system as Jequetepeque water users are willing to pay for water which is officially denied to them, because they for example did not pay the ISF of the present or past year(s). As these services are delivered unofficially it is difficult to tell how much money is involved. In the water flow measurement program in Chancay-Lambayeque, about 10% of the water deliveries observed in the field were not programmed. Some water users stated that they pay the same amount for an unofficial as for an official water turn. A very rough calculation of the money involved, based on the above assumption, in the *Comisión* of Lambayeque shows that the income from illegal water selling is US$ 6,000 (the official water sold is US$ 60,000 per year, thus 10% is US$ 6,000). This would be slightly more than the salaries of the field personnel working in that area (5 field workers, each earning US$ 1000 per year). It is unlikely that the field personnel can keep all the unofficial income themselves. The friendship between some *presidentes* and some of their field personnel, and also pressures put on other field personnel by the *presidentes* suggests that the field personnel need to share part of these unofficial income with their boss. There are no indications that jobs can be bought, as was found by Wade (1982) in India, but it is likely that money does flow up in the hierarchy in the way described by Wade. The keeping in place of the board of directors for eight years by the Ministry of Agriculture is a sign in that direction.

Officially, according to the Water Law (DS 037-89-AG, Capítulo XIII), each *Comisión* should have a *Comité de Honor* which should be formed by three to five ex-*presidentes* and the actual *presidente* of the *Comisión*. This 'Committee of Honour' has the role to monitor the functioning of the board of the *Comisión* and behaviour of the water users. However, none of the *Comisiones* in Chancay-Lambayeque or Jequetepeque have established a *Comité de Honor*. The main reason for this seems that the *presidente* does not want to be controlled by the Committee of Honor[8].

The staff of the *Comisión de Regantes* also has the task to monitor and punish breaking of rules in the domain of the *Comisión de Regantes*. The most common infraction is the stealing of water. The stealing of water inside the tertiary blocks (from one user by another user) is regarded as a problem of the water user whose turn is stolen. Thus, the *Comisión* does not deal with any water stealing inside the tertiary blocks. However, water stealing by taking more water from the secondary canal, by opening more the gate to a tertiary canal, is a matter

[8] Similar findings are presented by Huber (1990) for production co-operatives in the Coast of Peru.

dealt with by the *Comisión*. Normally the *sectorista* will monitor the water taking by the tertiary canals and will report any infraction to the engineer or *presidente*. They will normally levy a small fine to punish the offenders. If the water users do not accept the fine, the *presidente* might file a case against them with the ATDR. If the water users still do not want to pay their fine they may appeal against the fine of the ATDR with the Autonomous Watershed Authority (AACH). If the AACH rules in favour of the decision of the ATDR the water users, as a final step in the process of appeals, could start a civil court case against the AACH.

Offences might be discovered by routine inspection of the *sectorista* or *tomero,* but most cases of breaking of a rule are brought forward by the deprived party. For example, in the case of water stealing, the water user or group of water users that receive less water because of the illegal opening of a sluice gate upstream of their fields, will go to the engineer or *presidente* of the *Comisión* to complain. This is how many cases of water stealing, but also of illegal filling of drains to enlarge fields, and blocking access roads, reach the *Comisión*. However, in some cases the *presidente* (together with the engineer) will actively look for offences committed by a particular water user. They will do that to try to get this person convicted of an offence by the ATDR. A water user that is found guilty by the ATDR of violating an official rule is excluded for elections for the board of the *Comisión* for four years. This 'political use' of the sanctioning of offences is done to hinder water users that are engaged in the political competition for power in the *Comisión*.

The *presidente* and the engineer will resolve most problems themselves. As the *presidente* does not have detailed information and knowledge about the exact situation in the field (s)he will in most cases send the engineer to inspect the place and find out more about the offence. In the more important cases the *presidente* will go her or himself to hear the involved parties and make observations. As the *presidente* can officially not levy fines (s)he might either settle the case informally by mediation, or informally levy a fine, or send the case to the ATDR.

3.4.6 Board of directors of the Junta de Usuarios

The *Junta de Usuarios* is the 'federated' water users' association of all *Comisiones de Regantes* in an Irrigation District. The *Junta* can obtain a concession to operate and maintain the main system. The board of directors of the *Junta de Ususarios* is elected from the presidents of the *Comisiones de Regantes*. The board of the *Junta* is formed by the *presidente* (chairman of the board), the secretary (*secretario*), the treasurer (*tesorero*), the vice-presidente (*vice-presidente*) and two delegates from each of the *Comisiones* (*vocales*). It is interesting to notice that the delegates of the *Comisiones* never elect the *presidente* of the most important *Comisión* (this is CR Ferreñafe in Chancay-Lambayeque and CR Guadalupe in Jequetepeque) to become the *presidente* of the *Junta*. This creates a power balance in the board of the *Junta* as the most important *Comisión* is not allowed to obtain the key position in the management of the system.

Since the management turnover, the *presidente* of the *Junta* has an important role in the daily management of the main irrigation system. Officially it is not a paid job, but normally the *presidente* is occupied full time by the management of the system and receives compensation by a sort of daily allowance. The main tasks of the *presidente* are: maintain contacts with the local and national government organisations; maintain contacts with representatives of other irrigation systems and other relevant organisations (banks, NGOs, etc.); monitor the

4.2.3 Water title and access to infrastructure

A water title gives the right to a certain amount of water in a certain period. However, to actually get this water on one's plot one needs to have access to the infrastructure to convey the water to one's plot. In the three examples presented below it will be illustrated that the right to water should be seen as somewhat independent from the right to use infrastructure.

Example 1: *Tomas directas* cancelled

An example of a conflict on access to irrigation infrastructure is the conflict between the CR Sasape in Chancay-Lambayeque and the concerned water users that took place in 1998. A part of an existing secondary canal was redesigned to have fewer '*tomas directas*' (direct offtakes) to individual fields. The problem was that water theft could not be controlled with the high number of direct offtakes from the canal. The design and construction of the new part of the canal was done by the local NGO IMAR Costa Norte. The farmers who after the construction of the reshaped canal had no longer direct access to the secondary canal protested. First they went to the board of the *Comisión de Regantes*. As the board agreed with the reshaping of the canal, it did not do anything with the complaint of the farmers. Then the farmers filled part of the new canal with earth and opened up the old canal. After that the board of the *Comisión* filed a case against two water users (brothers) who were held responsible for destroying the canal. As this did not resolve the problem the board went to the ATDR. The ATDR gave a fine of US$ 200. The brothers refused to pay the fine. They claimed that they had the historic right to use the canal as it was. The brothers went to the AACH to have the fine cancelled. The AACH declared the appeal unfounded at the beginning of 1999.

Example 2: Water intake by EPSEL

EPSEL S.A. (Entidad Prestadora de Servicios de Saneamiento de Lambayeque) is the drinking water company providing water to the town of Chiclayo. Chiclayo has about 600.000 inhabitants and uses about 60 million cubic metres water per year (eight percent of the use for irrigation). The water comes from the same river and reservoir as the irrigation water for the Chancay-Lambayeque irrigation system. EPSEL is owned by the municipality of Chiclayo. EPSEL has its own small storage reservoir near Chiclayo and the water to fill this reservoir is taken from one of the secondary canals of the *Comisión de Regantes* Chiclayo. Although the *Junta de Usuarios* and the *Comisiones* recognised the right of EPSEL to take the 60 million cubic metres, there were ongoing disputes on the timing of the intake and ending of water intake from the canal without prior notification. EPSEL usually announced when they would start the intake of water, but did not notify when they would stop the intake. This caused problems because by just closing the intake structure the extra water flowing into the secondary canal could cause overtopping of the canal which was particularly unpleasant in the urban areas where floods might cause damage to houses.

In 1998 the *Junta de Usuarios* started a court case against EPSEL, because EPSEL reconstructed the intake structure without permission of the *Junta de Usuarios*. The canals are formally owned by the Ministry of Agriculture and the *Junta de Usuarios* only has a use-concession and manages the irrigation infrastructure[10]. EPSEL is the owner of the canal taking water to the drinking water reservoir, therefore, EPSEL did not see the need to ask the *Junta de Usuarios* permission to reshape the intake. The *Junta*, already irritated by the ongoing disputes on the intake of water, started the court cases to demonstrate its authority

[10] Actually it is not the *Junta de Usuarios* that has a use-concession of the secondary canals. The *Comisiones de Regantes* have these use-concessions, and ETECOM has the use-concession of the main system. However, the *Junta de Usuarios* regularly uses its authority to deal with issues inside the *Comisiones* and ETECOM.

over the secondary canal. The judge settled the case. The case is interesting because it demonstrates that access to water and access to infrastructure are perceived as separate things.

Example 3: A fight between neighbouring users over access to roads and canals
A typical conflict occurring at 'field level' is the following case from CR Pacanga, Jequetepeque. Two brothers had inherited land from their parents. The plot had been one plot and had one intake from the tertiary canal. After dividing the plot into two parts of equal size one plot no longer had direct access to the tertiary canal and also not to the access road. It then became necessary for this water user to lead the water from the tertiary canal over the land of his brother to his own plot: also to get access with a tractor to his plot he had to go over the land of his brother. Because of family fights the brothers were not on speaking terms and one brother did not allow the other brother to use part of his land to bring water or allow a tractor to cross his land. The deprived brother threatened to go to court over a period of several years to put pressure on his brother to settle the dispute and be able to make an extra field ditch and access road on his brothers land. To go to court would be a disgrace for the family and would involve a lot of costs. The brothers did not go to court and the deprived brother each year found a solution for the lack of direct access. For example not cultivating the plot, cultivating the plot with water brought by a temporary field ditch on another neighbours' field and not using a tractor.

The *Comisión*, *Junta*, ATDR and AACH can do little in these cases. The general rule is that each plot with a water right should have physical access to the tertiary canal and access road, but on the other hand they have no influence over the privately owned plots of the water users. Again this is an example where the conflict is not about the water right itself but about access to the infrastructure that conveys the water.

There are a lot of this type of disputes and conflicts between family members and buyers and sellers of land. For example a buyer of a piece of land discovers that the land that he bought in Chancay-Lambayeque actually had no water title attached to it. He bought it for US$ 6000 per ha which is the price for irrigated land as at the time of buying the land had actually been irrigated. After the sale it appeared that the former owner had irrigated the land with water allocated to another plot. The new owner did not have access to irrigation water from another plot and thus had bought a completely useless plot for a lot of money. Legally the buyer could do nothing and obtaining a water right officially would be impossible. Similar cases have been observed also between tenant and owner, and especially among heirs.

4.3 Planning of the water allocation per irrigation season

4.3.1 Prognosis and irrigation and crop plan

Besides determining who is entitled a water right, the ATDR also decides on the maximum volume to be allocated to each individual plot in a specific irrigation season. First of all the ATDR decides on what type of water right is assigned: a permanent right (*licencia*) or a right to excess water only (*permiso*). The type of right was determined once and for all directly after the Agrarian Reform in 1969. However, upon parcellation of the co-operatives the individual plots had to be assigned either a *licencia* or a *permiso* right. For example, if a co-operative had 80 percent *licencia* land and 20 percent *permiso* land inherited from the *hacienda*, this now could be divided in two ways. The first way was to create plots with completely *licencia* rights on 80 percent of the land and 20 percent parcels with only *permiso* land. An alternative parcellation would grant 80 percent *licencia* and 20 percent *permiso* water rights to each of the plots created. The co-operative members could decide themselves how to do it. Many co-operatives in Chancay-Lambayeque opted for the last option because it was considered more fair to distribute the water rights equally. This division makes it very difficult to actually check whether or not *permiso* land is irrigated in water scarce periods. The *permiso* land is scattered in small parts all over the place. In Jequetepeque the *permiso* land was concentrated in certain areas. Members of the co-operatives would get one plot in the *licencia* area and another smaller plot in the *permiso* area. The concentration of the *permiso* land makes it much easier to deny access to irrigation water in the *permiso* area in water scarce periods.

The ATDR decides on the crop allowed to be grown for all individual plots. The water users request to grow a certain crop before the irrigation season starts. This appears to be a very flexible and responsive way of allocating water, but in practice this is merely a time consuming formality. The ATDR, in fact, only permits production of a crop allowed the year before, or a crop that uses less water. Thus, a farmer that was allowed to grow rice last year will normally request to grow rice also the next year. A request to grow maize would be allowed by the ATDR because maize is assigned less volume of water than rice, but the farmer would never again regain the right to grow rice.

Thus, the officially allowed cropping pattern in the Irrigation Districts has remained pretty much the same the last 30 years. The crop permitted was based on the crop grown traditionally at the particular plot by the *hacienda,* or remained the same crop the smallholder used to grow. In this way the pattern in Chancay-Lambayeque of crop zones of sugarcane in the head-end, rice in the middle part and maize and beans in the tail-end, as established in the *hacienda* era, remained more or less in place. In Jequetepeque almost all areas are allowed to grow rice in water abundant years, but some places will have to switch to maize in dry periods according to rules explained below.

Each year in October the *Comité de Coordinación,* that is the ATDR together with the full board of the *Junta de Usuarios* (all *presidentes* of the *Comisiones de Regantes*), the representatives of the local production organisations and members of the local Ministry of Agriculture draw up the irrigation and cultivation plan (*Plan de Cultivos y Riego*, PCR). It is based on the predicted water supply (prognosis) and water demand from the users. Important for the start of the irrigation season is the volume of water in the reservoir. With a low reservoir it is risky to start rice irrigation early, because the supply in the river is irregular. The prognoses are based on the information from the national weather institute, SENAMHI, and own interpretations of the images showing deviations from the average temperatures of the ocean near the North Coast of Peru[11]. De Bruijn (1999) has shown that these prognoses are not reliable and in fact no predictions can be made on the rainfall in the coming season. Only probabilities can be calculated from past river discharges.

The prognosis is always on the safe side: all eleven prognoses from 1980 till 1991 were below actual water availability (*ibid.*: 65). This means that during the irrigation season there is more water available than planned. For the *Comisiones*, *Junta* and the ATDR this is much more

[11] A relative increase of the average temperature of about 2 or 3 degrees of the ocean water will increase the rainfall in the mountains. However, the relation between increase in temperature and rainfall is only clear in case of the extreme event of the El Niño rains (ocean temperature of +5° C above average). In normal years the relation between ocean temperature and an increase of rainfall do not show a correlation.

convenient than the opposite situation where the managers would have less water than planned.

The demand side of the planning is based on the water rights and crop zones. All registered water users with a *licencia* water right are asked to hand in a form asking which crop they would like to grow the coming season. In Chancay-Lambayeque, in practice, during the irrigation season not so much the crop itself matters, but the total volume of water requested (and only in water scarce periods). The crop in the field is not monitored but the volume allowed to be requested can be monitored depending on the water scarcity. Hence a farmer who was allowed to grow rice will always request to grow rice the next season even if the farmer is planning to grow another – less water consuming – crop in practice. Hence, in all years the crops requested, and therewith the total demand of water is more or less the same.

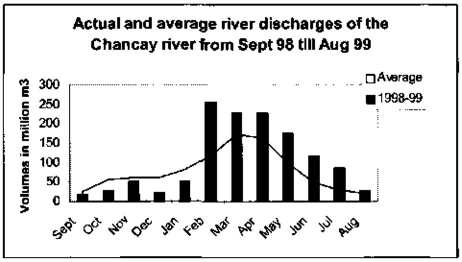
For each crop the ATDR has established a maximum volume of water to be requested per hectare per irrigation season (see Table 4.1). These volumes are called '*módulos*' or '*coeficiencias*' and might be different for each valley along the coast. It is not clear on what basis these volumes have been established. They were probably introduced in 1970 with the first calculation of the first irrigation plan. For Chancay-Lambayeque it could be that the German financed Tinajones project has calculated and/or measured these volumes.

Table 4.1: Maximum volumes of water (in m^3) to be requested per hectare per irrigation season in Chancay-Lambayeque and Jequetepeque (Sources: Carpio and Mejia 1996, De Bruijn 1999)

Crop	Chancay-Lambayeque	Jequetepeque
Sugarcane	20,000	22,000
Rice	14,000	14,000
Maize	7,100	7,100
Beans	4,200	4,200
Grass land	12,000	12,000
Alfalfa	12,000	12,000
Cotton	7,100	9,000
Sweet potato	3,000	3,000

In exceptional cases the crops requested (and allowed) can be different from the previous year. Two examples: when sugarcane production was not longer profitable anymore after the collapse of the sugarcane co-operatives mid 1990s, some small producers turned their sugarcane water rights into rice water rights, (they thus lost 4 to 6,000 m^3/ha per year, but gained access to water in November when rice seed beds are irrigated, but sugarcane is not getting water). A second example is maize growing fields that are affected very badly by the waterlogging and salinity caused by their neighbouring rice fields. These maize farmers are, after long procedures and a field inspection, allowed to grow rice to repress the salinity on their fields. This extension of the rice growing area is a slow, but annually recurring, process occurring on the borders of the rice growing area. In the future this will create a problem for the water supply of the whole system. At present this problem is not felt because the past three years were relatively wet, and the area actually cultivated under sugarcane has decreased because of problems in the sugarcane co-operatives (see section 2.4.2.).

Every year, at the beginning of the irrigation season, a document is given to each individual water user specifying the crop, area and consequently total volume allocated to them the



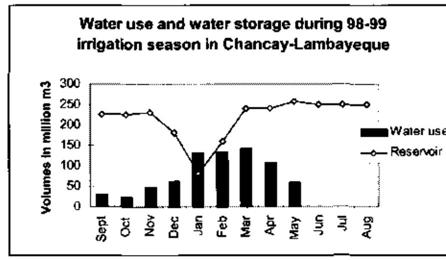


Figure 4.1: Water supply and demand in Chancay-Lambayeque in the 98-99 irrigation season (Source: records from the *Autoridad Autónoma*)

Box 4.1: Adjustments in the water planning during the irrigation season 1998-1999 in Chancay-Lambayeque

October 12, 1998: Forecast for the rainfall this year is: "it will be a normal year with a dry period in January and February". The *Comité de Coordinación* decides to start like in any normal year: the rice-irrigation can begin on November 15 in Chiclayo, Lambayeque, Monsefú and Chongoyape. On 1 December in Ferreñafe and Cachinche.

November 30: The planning of the total discharges for irrigation use are: December 15: 15 m^3/s; January 1st: 40 m^3/s and February 1st: 60 m^3/s.

December 10: There is only 5 m^3/s in the river. In addition, ATDR forecasts rains will only start in March. Thus rice can only receive a total of 12,000 m^3/ha, and maize cannot be grown during the rice irrigation season (but is allowed to be cultivated from May onwards). Most important decision: the reduction of the area with water allocation rights for rice (this reduction is called '*rangos*'), the reduction increases with the landholding:
0-3 ha: 100% has allocation right
3-6 ha: 80%
6-10 ha: 70%
10-20 ha: 60%
+ 20 ha: 50%

January 13, 1999: Still low flow in river (8 m^3/s), reservoir will be empty on February 15. Scheduling: max. 4 hours per hectare each 15 days for transplanting of rice and max. 1 hour per hectare each 15 days for the transplanted rice. Maximum total flow to irrigated area: 50 m^3/s (ATDR wanted 40 m^3/s).

January 20: Real water crisis! Only 3 hours per hectare/month for rice (this is 1650 m^3/ha per month, or only 90% of the ETc, without any compensation for the percolation losses in the fields). Maximum flow reduced to 40 m^3/s.

February 5: Rains have started! Flow to irrigated area increased to 56 m^3/s. Farmers are free to buy any volume of water. As the farmers did not follow up the '*rangos* rule', and planted all their land with rice, they are saved just in time. Now they are free to buy any volume of water they want. Also the *permiso* right holders can now request water for their maize.

June 4: Still sufficient water in river. *Presidente* of the *Junta* wants to reserve all water in the reservoir for the next season, and not provide water from the reservoir to the maize and bean growers in the tail-end areas. (The *presidente* of the *Junta* is a rice farmer himself)

August 11: From September 1 to October 15 no water in the canals because of the canal cleaning.

October 12: Tail-end water users want water from the reservoir. The *presidente* of the *Junta* only allows water for those farmers who do not have debts, have official water right (PCR) and already have requested the PCR for the coming season.

(Source: minutes book of the *Comité de Coordinación* at the ATDR office)

In years when the available water might be just sufficient to allow some more *campos* to grow rice the water users in the *campos* not allowed to grow rice will protest. Their main arguments are: that their soils are only suited for rice because of salinity; that their soils are heavy clay and thus would not need much water; that they need to grow rice to sustain their families; and that there is sufficient water according to them. The *Comisión* will use the authority of the *gerente técnico* of the *Junta de Usuarios* and the ATDR to convince the farmers that this year there is insufficient water to grow rice in their *campo*. The outcome of the negotiation process is in most cases that the farmers are not allowed to grow rice, or only in a small area of the *campo*.

The measures of *rangos* and *campos* can only be applied in the beginning of the rice irrigation season. As soon as a farmer is allowed to grow rice the areas can no longer be reduced. It can happen however that during the irrigation season the supply falls below the demand. Then the volumes per hectare are reduced and the order of the rotation of the plots along the tertiary canals is followed stricter. In case of severe water scarcity rotation of water among secondary canals will be practised. In that case for two weeks only half of the secondary canals run with water. After two weeks the dry canals get water and the other canals are cut off. If water gets even scarcer there will be rotation among the tertiary blocks along a secondary canal also.

The opposite situation also occurs: abundance of water. Then there is more water in the river than the water users want to buy. In Chancay-Lambayeque then it is the turn of the *sectoristas* to beg. They will try to persuade the farmers to buy water, because the water selling is needed for paying their salaries. In this case the rotation order along the canals is no longer respected and also farmers without permanent water title can request water. In really water abundant years the water that is not sold flows directly into the ocean. In Jequetepeque sale of additional water does not increase the income of the *Comisiones*. An exception are two *Comisiones* (San Pedro and San José) where they introduced volumetric water payment like in Chancay-Lambayeque. These two 'volumetric' *Comisiones* in Jequetepeque are discussed in section 4.4.2 and especially in sections 5.4.3 and 6.3.2.

4.3.3 The cropping plans in reality

Enforcing compliance with the cropping plan is a main problem in many large-scale irrigation systems throughout the world. Farmers often try to cultivate more water requiring crops than allowed, because they are often more profitable to grow. Usually the tail-end farmers suffer from the increased water consumption by the head and middle-reach water users.

In Chancay-Lambayeque the cropping zones are defined by the *Comité de Coordinación*. The enforcement of the cropping plan is the domain of the *Comisiones de Regantes*. The *Comisiones* have two means in the scheduling of water turns to enforce the cropping plan. The first is the timing of water delivery to certain areas. For example, only in the head-end water is made available throughout the year. This allows the growing of sugarcane. As between July and October the remainder of the irrigation scheme does not get irrigation water, growing of sugarcane is impossible without pumping of groundwater outside the sugarcane area. As use of groundwater is considered too expensive no sugarcane is grown in the middle and tail-end areas. The same measure is applied to limit the rice growing area. Water for the rice nurseries is only released to certain areas, while keeping the maize-zone without any water supply. Interestingly, some farmers get round this difficulty by transporting seedlings from rice areas to non-rice areas. Many pick-up trucks loaded with bundles of seedlings can be seen driving from the rice-zone into the maize-zone in January. However, this does not affect too much the overall measure of limiting the rice zone, because the second measure of the *Comisiones* is the control over the total volume of water scheduled to each plot.

Farmers in the maize-zone can only request water to the maximum of the *módulo* for maize (7,100 m^3/ha) per season. However, as discussed in the section above, the *Comisiones* do not restrict the selling of water to any farmer in water abundant years, because any water sold increases the income of the *Comisiones*. Nevertheless, in water scarce periods the cropping plan is functional. Water restrictions in those periods depend on the crop allowed to be grown (and the size of the plot). Thus, farmers might start to grow rice in the maize-zone (with seedlings bought from the rice-area and water requested for maize) on a part of their land. However this is a big risk, because in water scarce periods the reduction of water supply will be as if maize was grown and be insufficient to produce a good rice crop on the entire plot.

It is estimated that in Chancay-Lambayeque some ten percent of the maize-zone was illegally grown with rice in the 1999-2000 irrigation season. Thus, overall the control measures of the *Comisiones* seem to be quite effective. Illegal rice growing was particularly observed near the official rice-zone. Most probably because in these areas the salinisation due to waterlogging inhibits the growth of any other crop besides rice, and because of the relative short distance for the transport of rice seedlings.

In Jequetepeque the enforcement of the cropping plan by the *Comisiones de Regantes* is effectuated by the timing and regulation of the water supply to each *campo*. A *campo* that is not allowed to grow rice will not get water during the rice nursery period. Also the volumes of water delivered to such *campo* will be sufficient for maize only. Nevertheless, as in Chancay, farmers can get round this measure by using groundwater or transporting rice seedlings from rice-zones. In Jequetepeque this non-compliance to the cropping plan affects the fee recovery. Thus, unlike Chancay, illegal rice growing is punished by the ATDR in Jequetepeque. Thus, illegal rice growing is limited to some relative small areas where natural springs provide water all year.

4.4 Daily practices of water scheduling

4.4.1 Scheduling in Chancay-Lambayeque

In Chancay-Lambayeque the users request water turns at the office of the *Comisión de Regantes* (Photo 4.1). They order a number of hours with the *sectorista* in the morning, and get a receipt indicating the hour for starting and ending of the irrigation turn, after they have paid the corresponding amount at the cashier. The flow at field level is 160 or sometimes 80 l/s. The turns cannot be delivered just any time, a fixed order along the tertiary canal is followed from tail-end to head-end. Within one tertiary block one to four water users might have an irrigation turn at the same time. This implies that more or less 640 l/s (4 times 160 l/s), plus some 80 l/s extra to compensate seepage losses, should be entering the tertiary unit. The 'units of continuous water flow of 160 l/s' are called '*mitas*'. A *mita* is rotated among the water users in a certain part of the tertiary unit. When water demand is low one *mita* is rotated among all users in a tertiary block. At times of high demand for water up to four *mitas* are delivered and split up inside the tertiary unit (depending on its size). To know how much water should be delivered by the ETECOM to a certain secondary canal, they add up the number of *mitas* of the tertiary blocks served by that secondary canal.

Photo 4.1: Water users requesting water turns in the morning with the *sectorista* in the office of the CR Lambayeque

Every day the *sectoristas* decide how many *mitas* are to be delivered to each tertiary block. This is an important decision because too few *mitas* would decrease the irrigation frequency for each field to less than once in the 15 days. Too many *mitas* are not a problem for the farmers, but would mean that after certain time no farmers want to buy turns and thus the *mitas* have to be stopped. This costs labour and causes water losses because extra filling of canals is needed. Thus each day the *sectoristas* have to estimate how many farmers are willing to buy how many hours of water to have a frequency of about one complete rotation each 15 days.

All farmers requesting an irrigation turn at the office of the *Comisión de Regantes* have to wait their turn in the office of the *Comisión*.. Beforehand it is hard to predict when a farmer will have a turn. The number of hours each farmer can buy is free (unless water scarcity introduces a quota), and not all farmers will always buy a water turn. Thus the beginning of the turn of a certain water user also depends on the number of hours his or her downstream neighbours buy. A turn can only be bought one day before the turn is scheduled. This means that water users sometimes go two to three consecutive days to the office before they finally can buy a turn. In normal periods, a water user can buy a water turn each two weeks. If water is really abundant, water users can buy water more frequently also, and not necessarily following the order of the fields along the canal.

Every morning the *sectorista* fills in the scheduling-forms for each tertiary block. The form states the name and number of each water user and the time of start and finish of the turn. This is a provisional form, because the schedule is only official after all scheduled farmers have paid. Thus, a group of farmers from a branch of the tertiary canal rotating one *mita* gather at 8 am in the office of the *Comisión*, the *sectorista* draws up a provisional schedule between 9 and 10 am, and the farmers pay and receive their receipt at 10:30 am. The official schedule is registered in the SARA-computer system by the cashier of the ETECOM located in the offices of each *Comisión de Regantes*. SARA is the acronym of '*Sistema de*

Administración y Registro de Agua' (Administrative system for the registration of water). It was developed by the *Junta* with the support of IMAR Costa Norte. With the automated administration is becomes easy to monitor the volumes of water to be distributed per day and the monitor the volumes allocated to each individual water user, each tertiary block, or each secondary canal.

Irrigation delivery is 24 hours per day. No special arrangements are made to distinguish between day and night irrigation. Farmers do not complain when they have to irrigate at night. Statistical analyses from the schedules did not point out any preferential treatment for a certain group of farmers in respect of day and night irrigation. Preferences were checked for landholding size and gender.

The secondary canals – operated by the *Comisiones* - are assigned a certain flow of water on a daily basis according to the number of *mitas* assigned by the *sectoristas* to the tertiary blocks. Each *mita* gets 200 l/s at the entrance of the secondary canal. That means a 25 percent compensation for the seepage losses in the secondary and tertiary canals. The flow at the entrance of the field should be 160 l/s. The compensation rate does not change during the irrigation season, although the actual seepage decreases during the season because of the increased saturation of the soil and the raised level of the groundwater. All secondary canals receive the same 25 percent, although some canals have much higher losses and others have fewer losses according to soil type, discharge and groundwater table. The *Comisiones* have some flexibility to play around with the flows. They can compensate higher losses in a canal by taking water from another canal that might have fewer losses. Most *Comisiones* complain that the 25 percent is too low to compensate the actual losses.

The farmers pay only the hours the water is actually flowing into their fields. The hours needed to bring the water flow to their fields are scheduled but not paid for by the farmer. Also hours needed to 'head up' the water to be able to irrigate a 'high' field are scheduled and not paid for. The *sectorista* makes estimations for the number of hours needed for this purpose. The actual hours needed are not checked in the field, so the allocation of these free-of-cost-hours is a subject of negotiation: the farmers always wanting more hours (hoping to get free water on their field) and the *sectorista* wanting to give as little free water as possible because the engineer of the *Comisión* checks the percentages of free hours given, compared with former years and other sectors. If the percentage of free hours is relatively high the *sectorista* might be accused of corruption. The number of free hours given to a water user is also closely watched by the other farmers in the tertiary block at the meetings when the hours are scheduled. If some farmer is suspected to get too many compensation hours the other farmers will also claim more free-of-cost hours. Still it is widely known that the compensation hours are sold illegally to water users. The involved water user profits from the lower price, the *sectorista* profits because he can put the money in his own pocket, and the *Comisión* and *Junta* suffer because they receive less ISF (see also section 6.3.1.).

Another type of free hours are those scheduled to compensate for hours paid for but not delivered. This noncompliance with the scheduling can be caused by unexpected low river flow, canal or division structure break down, water stealing, or error in delivery. In the two tertiary blocks studied, in total about 18 percent of the hours scheduled is for filling up canals and compensation, and thus not paid for officially. In the tail-end tertiary block Sialupe-Sodecape in CR Muy Finca the hours to compensate (8%) were much more than in tertiary block La Ladrillera-La Colorada in middle-reach CR Lambayeque (2%).

An important exception to this mode of scheduling are the three sugarcane co-operatives in the head-end of the Chancay-Lambayeque system. They have the customary right (and physical position) to take any amount of water their canals can take and whenever they like without prior warning. This system is called '*toma libre*' and has been the rule since many centuries. Part of the overuse of water flows back in the river via the groundwater and is used again downstream.

In time of water scarcity during the irrigation season the allocation of water to the users is restricted[12]. The maximum number of hours to be requested per turn is limited, for example to three hours once in the 15 days per hectare of rice with *licencia* (see the example in Box 4.1). The hours still have to be bought at the *Comisión*, and a farmer can still decide to buy less or no hours. But as all farmers will request their maximum amount of water, the allocation system thus becomes a fixed rotation. As was shown in the example in Box 4.1 in times of prolonged water scarcity at the beginning of the rice irrigation season the *Comité de Coordinación* enforces *rangos*. In that case only the area of each plot within the *rangos* are considered for the scheduling of the fixed number of hours.

An important effect of the individual scheduling of each turn is the possibility to exclude an individual farmer from water at the start or during the irrigation season. Farmers with debts or who have to pay fines are denied a water turn. In times when the water is not scarce water users can easily evade this 'obligatory point of passage' by asking a neighbouring farmer to buy some extra hours, which the excluded farmer then buys from this neighbour. In times of water scarcity this is much more difficult because each water user will use their full quota.

Although in most *Comisiones* in Chancay-Lambayeque the water users have to go to the office of the *Comisión* to buy a water turn, in some *Comisiones* a *repartidor* schedules the water turns during a meeting held each morning somewhere in the tertiary block. The NGO IMAR Costa Norte spent much energy on having *repartidores* schedule and divide the water turns inside the tertiary blocks. The *sectorista* tells the *repartidor* how many *mitas* will be assigned to his tertiary block. The *repartidor* then can schedule these *mitas* and takes the money from the water users in the field. Later the same day the *repartidor* will go to the office of the *Comisión* to pay the money received for the hours scheduled and register the hours officially. The advantage for the water users is that they do not need to go to the office of the *Comisión*, thus saving money and time. The advantage for the *sectorista* is that he has less work burden, because the scheduling is done for him. Also the *repartidor* knows better the farmers, their fields and the canals of the tertiary block and can thus better schedule the water turns. The water users pay a little extra fee per *riego* to the *repartidor* for his work. Although the decentralised system seems to have only advantages, many persons in the board of the *Comisiones*, and especially ETECOM (responsible for the recovery of the ISF), were against the *repartidor* collecting the ISF. They said is would be too dangerous for the *repartidor* to carry so much money on him, but more likely the ETECOM and *Comisiones* did not like to lose control over the scheduling and money collection to more decentralised levels.

In Box 4.2 an impression is given of the negotiations and disputes happening during the meetings in which the *repartidor* schedules the water turns. It shows how different local rules are used to claim water turns.

[12] Theoretically the total volume of water to be bought per hectare in one irrigation season is also restricted in water abundant situations: the *módulos de riego*: e.g. 14,000 m^3/ha of paddy per year. However, it is in the interest of the *Comisión* to sell as much water as possible, so in wet years the official restriction is not applied.

Box 4.2: Competition and competence in scheduling at the tertiary canal in *Comité de Canal* La Ladrillera, CR Lambayeque

3rd of January 2000

Fifteen water users (including two women) of tertiary canal La Ladrillera have gathered at 8:20 AM at the spot along a branch canal where scheduling of water turns is done each morning (Photo 4.2). The *repartidor* Humberto arrives ten minutes later. Humberto immediately starts scheduling the water turns of some of the present water users. There is a dispute on the priority of the turns (Photo 4.3). One group of farmers wants water for their rice seedbed, the other group wants water to wet their dry lands for rice transplanting. The problem is that the turns for wetting of the big rice plots takes a long time (24 hours for 8 ha), and the seedbeds need, although little, but quite often an irrigation turn. The farmers with a rice seedbed claim that they should have priority because at this stage the irrigation for the seedbeds is critical and the transplanting of the others can wait some days until all will start the transplanting. The farmers who want water for transplanting claim their turns on the basis that it is their turn now in the order of the fields along the canal. Humberto decides that the rice seedbeds go first, but that he will give only one hour to each farmer with a seedbed. The seedbed-farmers protest. They claim at least two hours (see Photo 4.4), but Humberto suspects they will use the extra water to start wetting their fields themselves. After the scheduling is done the farmers ask Humberto to really keep the order along the canal and not schedule any turns for farmers that were not present during the meeting: the farmer who missed her/his turn should wait until the rotation schedule has completed and returns to their plots. Some farmers arrive late but can still buy water turns, some farmers buy water for themselves and two other water users.

Photo 4.2: Water users at the meeting point

Photo 4.3: Angry water users during the meeting to schedule water turns

4th of January

The farmers still only receive water for seedbeds. However, most farmers have started transplanting at least on part of their land. They use the water turns assigned for the seedbeds partly for the seedbed and the *patera* (part of the field used as reservoir) and if possible also some more basins. The *patera* and the wetted basins are transplanted with rice. At the scheduling-meeting that morning a farmer asks for 6 hours and gets 3 hours (1 irrigation hour and 2 hours to fill the canal up to his parcel). Later it was observed that the water reached his plot earlier and he was wetting land for transplanting rice.

10th of January

Twenty farmers await Humberto in the morning. When he arrives he says he is late because he had to check a gate of which the padlock had been broken last night. He knows who did it and writes out a fine. A problem is that all need water now for transplanting. A group of farmers say they have been coming each morning the past days to claim water but they still have not been scheduled. One farmer in particular seems to be a sort of 'spokesman' for this group. A rich farmer has already transplanted all his land and now comes to claim a water turn to refill the rice basins. The main concern of the farmers is that they want to transplant as soon as possible now because the price of day labour will rise in the coming days as more areas in the irrigation system start transplanting. Another reason to transplant soon is that the rice seedlings should not grow too big, as 'old' seedlings have less stooling and thus less production. The farmers therefore are happy with the relatively cool weather the last days reducing the growth of the seedlings. Humerto checks carefully his book on the water turns. Also the *presidente* of the *Comité de Canal* keeps records of the water turns (Photo 4.5).

Photo 4.4: Water user claiming two hours

19th of January

Humberto again arrives late. The water users, while waiting, discuss various topics: qualities of different rice varieties, and the weather forecasts of SENAMHI (Photo 4.6). The big landowner who has land at the head-end of the La Ladrillera canal is angry at a small landowner who has land at the tail-end of the same canal. The big landowner: "don't ever more touch the gate at the intake of my field!, or else…". The small land owner replies: "but you always steal our water, and Humberto was there when we closed the gate". The big landowner: "I had an official water turn!". Then Humberto arrives and the quarrelling water users silence. The last plots now get their

Photo 4.5: The *presidente* and the *repartidor* checking their books

first irrigation for transplanting, however, plots that have been transplanted have not received the second water turn, some are already 20 days after the first irrigation. In the parts with lighter soils this means no water is standing on the field and soils start cracking, this is a great threat for the water user who might lose her/his crop. Therefore, the farmers had gone some days before to the president of the *Comisión de Regantes* to claim more water for their tertiary block. The president and the *coordinador técnico* had visited the tertiary block the day before. Now the farmers say to Humberto he should claim an extra *mita* for their tertiary block.

Photo 4.6: Water users discussing among themselves

22nd of January

Twenty water users have gathered at the meeting point. Five of them are women and they are angry (Photo 4.7). They are angry because Humberto had scheduled a water turn for the water user that broke the padlock of a gate in the night of 9 to 10th of January and stole water. According to the women the offender should not be included in the normal rotation order as this would mean he would already get another water turn 12 days after he took water illegally, while they themselves already were waiting for more than 25 days for a water turn: "then we rather all break padlocks and steal water!" the women state. Humberto replies it was the *presidente* of the *Comité de Canal* that ordered him to give a water turn to the offender. Water is really scarce and almost all water users have not irrigated more than 20 days after the transplanting and face losing their crop. An intense dispute arises among the water users on what rule to follow in the order of the water turns: some opt for strictly following the order along the canal from tail to head-end (this is the 'official' rule). Others say that to protect the rice seedlings from withering the rotation should follow the transplanting dates (so who transplanted first should get water first). Others argue that the order of the water turns should be according the water need of the crops. Some fields on sandy soils dry up much quicker than other fields, thus the *presidente* of the *Comité* should do field inspections and determine which fields need irrigation first. At the end of the meeting no clear decision is taken. The water users seem totally unclear about the rules that will be followed.

Photo 4.7: A female water user arguing with the *repartidor*

29th of January

A special meeting is organised by NGO IMAR Costa Norte (IMAR still tries to monitor the functioning of Humberto as it was part of the project of IMAR to have *repartidor*es in the tertiary blocks). In the crisis meeting 30 water users of La Ladrillera are present (the big landowner is not). Four water users want to sack Humberto because he is not functioning well. An example is the preferences given to certain water users, including the one that broke a padlock and stole water. Another issue is that still not all users have cleaned their part of the canal, among them the big landowner. Furthermore, the farmers do not trust the water measurements of the *Comisión de Regantes* (Photos 4.8 and 4.9). Some farmers suggest to buy a current meter themselves to measure the water flow to their tertiary canal. Lastly they demand a fair share of the water allocated to the secondary canal. According to them this is 28 percent of the water in the secondary canal.

Photo 4.8: Staff of the *Comisión* is conducting a flow measument with a current meter in the tertiary canal La Ladrillera

9th of February

Finally more water in the river has resulted in more frequent water turns and all water users have been able to irrigate the hours they wanted. Humberto is now really looking for farmers who would like to buy some hours, most do not want to irrigate also because they applied nitrogen fertiliser and irrigation would move the nitrogen to one side of the field.

17th of February

The farmers are fighting again about water turns. As all had applied fertiliser last week and did not want to irrigate last week, but now need to irrigate because the nitrogen might 'burn' the rice plants if the soil would dry up. Again the fights start on the rule to be applied to establish the order of the turns. Some now suggest to use the date of nitrogen application, others still claim either the transplanting data, the order along the canal or on need of the crop. Clearly all claim the rule that would suit their particular case. Humberto decides to use the nitrogen application date but also more or less the order along the canal. In the end the big landowner gets 15 hours.

Photo 4.9: The *sectorista* calculating the discharge just measured

4.4.2 Scheduling in Jequetepeque

In Jequetepeque the flow entering the secondary canals is determined in a weekly meeting between the engineers of all thirteen *Comisiones* and the engineer (*gerente técnico*) of the *Junta de Usuarios*. A fixed flow is planned to flow to each *Comisión* during the week after the meeting. The amount of water assigned to each *Comisión* is calculated from the theoretical *módulos* (depending on the crop stage) and areas per crop established by the *Plan de Cultivo y Riego*. Thus the allocation of water to the *Comisiones* is pretty much fixed for the complete irrigation season. In the weekly meeting the engineers negotiate about the extra water assigned to each *Comisión* to compensate for canal seepage losses. The losses decrease during the irrigation season because of saturation of the soils and waterlogging. Compensation for seepage losses can be from 0 to 70%, but on average it is about 25%. The compensation given for water losses is very important because it is related with illegal money making (like the compensation hours given to individual farmers in Chancay-Lambayeque). In Jequetepeque the illegal money can be made by the staff or board members that sell irrigation water to farmers that have no PCR and thus did not pay the ISF. Thus, the more extra compensation water is allocated to a *Comisión*, the more illegal money can be made. If one *Comisión* is assigned a compensation considerably higher than the other *Comisiones,* or higher than the compensation given to that *Comisión* in former years, the engineers from other *Comisiones* will surely pressure the *gerente técnico* of the *Junta* not to give extra compensation water. The social control among the engineers, and the strict water allocation by the *gerente técnico*, are important factors preventing one or more *Comisiones* from getting a lot of 'free' water under the guise of compensation for seepage losses. The social control among engineers, more or less equal in power, prevents rent-seeking to severely obstruct the fee recovery. The exact amount of water needed to truly compensate for seepage losses is very difficult to determine. It is estimated that in total more or less 20% more land is irrigated than officially paid for. This is partly by illegal selling of water and partly by re-use of water from drains.

In Jequetepeque, in normal years, the water inside the tertiary blocks is not scheduled in turns to individual plots. The water runs continuously to all plots and from one plot to another plot. An exception is the beginning of the rice irrigation season. Then, water is scheduled in fixed rotations. The flow at field level is 30 to 90 l/s (the unit of distribution is '*tabla*'; one *tabla* is 30 l/s). To start irrigating the water users have to go the office of the *Comisión de Regantes* and pay (possible) debts and the ISF part for the beginning of the season. The scheduling of the turns happens similar to how this is done in Chancay-Lambayeque. The water users go to the office of their *Comisión de Regantes*, pay the ISF, and are scheduled. Next irrigation turns, however, are mostly requested from the *canalero* (ditch rider in similar function as the *sectorista* in Chancay-Lambayeque) in the field.

After the transplanting the water runs continuously to all plots. Water supply is controlled at the entrance of the secondary canals and to a lesser extent at points along the secondary canals. The water supply is so abundant that no exact scheduling is needed and water users more or less regulate the gates and field openings to get the water they want. However, some scheduling is still needed. Paddy farmers will not irrigate during more or less one week after applying fertiliser. They simply block the intakes to their fields without prior notice. If many farmers will apply fertiliser at the same time this will lead to a significant decrease in water demand. Therefore, the '*delgado del ramal*' (informal leader of the farmers in one tertiary block) will inform the *canalero* one week in advance when and how many farmers will apply fertiliser.

It is important for this case study to mention that two out of the thirteen *Comisiones* had introduced volumetric payment and scheduling in turns, like they did in Chancay-Lambayeque. These *Comisiones* were San José and San Pedro and are two relatively large *Comisiones* situated on the left bank of the Jequetepeque river. Here also, the reason for switching from flat-rates to volumetric charging was the fee-recovery during the irrigation season. Thus, in these *Comisiones*, as in Chancay-Lambayeque, the water users had to come to the office of the *Comisión* to get their water turns scheduled and to pay for them.

Similar to Chancay-Lambayeque the turns of the water users were scheduled in order from tail-end to head-end along the tertiary canals. However, the allocation of free hours to compensate for losses was monitored less strictly. Therefore, many 'free hours' were scheduled, hampering the fee-recovery. This free water is, however, not sold illegally to the water users because farmers have to pay the total volume allocated to them per hectare per irrigation season (the *módulo*) at the end of the irrigation season, regardless of the fact that they requested less water. Thus paying the *canalero* for an illegal 'free' water turn would mean paying for this water twice. The free hours are wanted by the water users because the free water means they only have to pay at the end of the irrigation season and not when the irrigation turn is scheduled. The payment afterwards is preferred by most farmers. As water is much more abundant in Jequetepeque compared to Chancay-Lambayeque, many water users have access to water flowing from other fields, and do not need to request (and pay) water turns. It can be concluded that the volumetric payment and scheduling in the two *Comisiones* in Jequetepeque is much less effective compared to Chancay-Lambayeque. This is mainly caused by the fact that farmers pay the total official *módulo* anyway at the end of the season, and because water is so abundant that many farmers receive water flowing from other fields.

4.5 Conclusions

The chapter has shown that actual volumetric water allocations are an outcome of many processes beyond the farmers requesting water curtailed by price-incentives, and government agencies setting maximum volumes. In practice, interactions - of both users' as well as governmental organisations using State law, and local regulations and negotiations - shape the allocation processes. Regulation, co-operation and competition play a role in the interactions.

Regulation of water allocation is based on both State law and regulations, and customary rights developed locally. The selection of water users is the exclusive domain of the governmental ATDR. The selection is based on historic rights and political decisions. Government also determines the crops allowed to be cultivated and the maximum volume of water to be applied per hectare of a certain crop per irrigation season ('*módulos*'). It is also State regulations that set the governance structure and the domains of decision-making of the involved organisations. However, local rules were developed in the Irrigation Districts to come to specific arrangements for water allocation and scheduling in water scarce periods. Furthermore, it is not only the total volumes of water allocated per season that are important, it is also the timing. The crop plan is enforced by allocating water to particular zones (and users) only in particular periods. Therewith, sugarcane and rice cultivation can be limited to certain zones.

Co-operation in water allocation occurs between the ATDR and the *Comisiones de Regantes*. In the *Comité de Coordinación* the *presidentes* of all *Comisiones* and the engineer of the

ATDR discuss the cropping plan before the irrigation season. During the irrigation season the *Comité de Coordinación* discusses any adaptations necessary because of less water availability. Although the ATDR officially approves the cropping plan and adaptations, the participation in decision making by the *Comisiones de Regantes* is crucial. The ATDR relies on the *Comisiones* for the execution of the cropping plan and restrictions in water scheduling. The ATDR has only 'remote control' over this execution. Therefore, it is important that the *Comisiones* agree to the final plans approved by the ATDR. The local procedures to deal with (unexpected) low river flows (e.g. '*rangos*' and '*campos*') have evolved historically and deal in particular ways with equity and possibilities of control and vigilance. Still these measures cause disputes. The rules and arguments used in these disputes are internal to the organisation and not put on paper. The *Comisiones* use a mix of technical arguments (soil type, volumes of water in the reservoir) and rules based on past practices to legitimise their decisions. The *Comisiones* execute these measures, but use the authority of the ATDR to convince the water users of the legitimacy of the measures. (Dealing with claims for water of individuals and groups of farmers is one of the main problems for the *Comisiones* in water scarce periods.)

Competition occurs because water is a contested resource and allocation includes and excludes people, affecting their livelihoods. Competition among competitors for water contributes to mechanisms of mutual social control (among engineers of *Comisiones*, or among water users in tertiary blocks). Competition makes that stakeholders have interests in actively monitoring of rule violation and sanctioning. Thus, competition also leads to accountability between different levels (water users claim their right to the established volumes of water). Competition between unequal stakeholders is illustrated with the extensions of the Chancay-Lambayeque and Jequetepeque irrigation systems. Government could expand the Chancay-Lambayeque system after the Tinajones project, because of the temporary increase of political power of the government vis-à-vis the water users. In Jequetepeque the government and *Junta* are still fighting over the extension of the system. The cases show that while the government sees itself as owner of the water and can re-allocate water to new users, the water users claim customary rights. Final outcomes of these allocation processes depend much on political power relations. Nevertheless, inside the Irrigation Districts the rules for water allocation are quite strictly followed without much political or social power interference (This says however little about the actual distribution of water, dealt with in Chapter 5). Price-incentives play a very minor role in water (re-)allocation. Although in Chancay-Lambayeque water is sold at a significant price per cubic metre, water allocation is not much influenced by it. If available, water users buy the water they perceive as needed. In water scarce periods, water use is restricted by rationing measures (based on equity, customary rights and technical criteria, and not market forces).

5. The performance of volumetric water distribution

5.1 Introduction

In Chapter 1 the discussions on volumetric water distribution were introduced. Briefly put, unsteady flow in large irrigation systems with variable and unpredictable inflow and on-request water scheduling is thought to inhibit a proper delivery of the programmed water turns. One group of experts favours automation of flow control, another group favours simple and transparent distribution systems like fixed proportional division systems.

It will be shown in this chapter that the water delivery performance in Chancay-Lambayeque was found to be quite good. This is a surprising finding, because the inflow of the Chancay river was very irregular and unpredictable (and the reservoir relatively small); the canals were open and unlined; the division structures were underflow sliding gates operated manually by formally untrained personnel; there were few flow measurement structures; and the scheduling was done on request of the many individual smallholders. This 'nightmare' system functioned well! How can this be explained?

This chapter undertakes this explanation by studying the technical and institutional factors influencing the delivery and analysing them together. First a framework is presented that helps to analyse the factors influencing the actual water delivery starting from the three most important factors directly involved in the water delivery: the irrigation infrastructure, the operators and the water users. The second part of this chapter looks at water operations and makes an assessment of water delivery performance in the two systems.

5.2 A framework to assess water distribution performance

5.2.1 Introduction

The actual water delivery in the two irrigation systems was assessed using the Delivery Performance Ratio (DPR) as an indicator. The Delivery Performance Ratio is defined as the match between the actual water delivery at a certain point in the system with the planned water delivery at that point at a certain time. The DPR tells us something about the operation of the division structures (do the operators set the gates according to the schedule) and whether or not this schedule is possible to execute in relation to the available water. It must be noted that looking at the DPR is only useful in a situation where water supply is neither extremely scarce nor extremely abundant in relation to the demand. It must also be noted that the DPR does not say anything on the match between the crop water requirements and the actual water supply. The DPR only says something on how well the water is distributed according to the planned schedule. Whether or not the schedule is socially acceptable, covers crop water requirements, and leads to optimal productivity of land, water and/or labour is very important to investigate, but forms no part of the assessment of the delivery performance.

In literature on water delivery performance of large-scale gravity irrigation systems two 'types' of studies can be found. One focuses on the design and typology of canals and control structures, and the conditions under which what type of technology might perform best. The other looks at the actual operation of existing infrastructure and searches for ways to improve the operation of these systems.

Within the first type we find different typologies of water supply like the one from Burns (1993), Murray-Rust and Snellen (1993), Plusquellec *et al.* (1994), Lankford and Gowing (1996) and Horst (1998). The variables that are used relate to the division structures directly - like manually operated or fixed, overflow or underflow - or to the way the structures are used: for example just-on-time delivery versus structured systems. The authors clearly demonstrate preferences for certain types of structures and operation modes. The general tendency is to promote simple-to-operate, transparent, and hydraulically stable structures, and not to try to have just-on-time deliveries with manually operated undershot gates. Doing more water flow measurements is frequently mentioned as a prerequisite to better water delivery performance.

The other type of writing on water delivery performance looks at the actual operation of existing infrastructure. Some authors describe the day-to-day operation as executed by the operators (Murray-Rust and Moore 1983, Van der Zaag 1992, Sloan 1997, Bautista *et al.* 2000, Loof *et al.* 2000). Others give an assessment of the water delivery performance (Murray-Rust and Snellen 1993, Sanaee-Jahromi *et al.* 2000), and yet others model different operational procedures and test them with canal simulations based on the existing infrastructure (Kuper 1997, Godaliyadda *et al.* 1999).

What has not been done (and will be done in this study) is to integrate the institutional factors, water availability and physical infrastructure, and relate these to actually observed canal operation and delivery performance ratios. In order to do this, a framework was developed integrating these factors. The framework presented below first addresses relative water supply, then the three main factors: infrastructure, operators and water users.

5.2.2 Relative water supply

The evaluation of performance should be seen in relation to the need for good performance. In a water abundant situation (where there is no alternative use of the water elsewhere in the catchment and no capacity to store water for drier periods, e.g. monsoon in Southeast Asia) the need for good delivery performance is less (although in systems with abundant water supply tail-end areas might still suffer from poor delivery). In extreme water scarce situations, measurement of water delivery performance is also less useful: the actual distribution as evaluated against the planned scheduling says little about the performance of the system regarding the provision of water to the crops. Relative Water Supply (RWS) can be defined as the ratio between the supply and the crop water demand at any level in the system (Keller 1986). We can thus come to a simple model, similar to the participation in water management model presented by Uphoff *et al.* (1990)[1]: only in a situation in which there is more or less a balance between supply and demand (there is sufficient or not quite enough) it is 'rational'

[1] Also Wade (1990) identifies RWS as a key factor in the success of the operation of an irrigation system.

from a water-productivity point of view to invest in water management to optimise the delivery. The RWS at field level would then be somewhere between 0.8 and 1.5. If the RWS is higher, water productivity would increase with expanding the cropped area or cultivating crops with higher water requirements. If RWS is below 0.8 severe water stress would occur that could only be alleviated by reducing the area and/or growing less water demanding crops.

The framework presented below focuses on situations where water availability is more or less 'just enough' to meet demands, and only seasonal fluctuations in water supply and/or water management may cause temporary situations of scarcity or abundance.

5.2.3 *Infrastructure*

Murray-Rust and Snellen (1993) present an evaluation framework in which they make a distinction between upstream and downstream controlled systems, and different types of fixed and gated division systems. Plusquellec *et al.* (1994), Horst (1998), Mollinga (1998a) and Godaliyadda *et al.* (1999) provide some more ideas as how to analyse physical irrigation infrastructure in relation to water delivery performance. From these ideas three questions can be formulated to analyse the influence of infrastructure on water delivery performance:

- How difficult is it to operate the gates in a way the target flows and water levels are achieved?
- How do negative and positive flow disturbances propagate downwards through the irrigation canals?
- How tamper-proof (robust) and transparent are the division structures?

To answer these questions specific properties of the division structures and canal system are studied. Unsteady flow, lag time and response time are important when studying the hydraulic behaviour of the canals and control structures. If gate settings are changed on a regular basis the flows in the canals will fluctuate (unsteady flow). The lag time is the time needed for a flow rate change to reach the delivery point. The response time of a system is the time required for a system to transit from the previous steady state into the desired steady state.

The layout of the canals itself influences the water delivery. For example, a tree-like structure of the canals is supposed to spread fluctuations more equally over the system than a hierarchical structure. Canals should have sufficient capacity for peak flows and might act as buffer reservoirs. They should not, however, have over-capacity. Overflow check structures in the ongoing canals to maintain the water level are supposed to increase the performance. Measurement structures might facilitate the operation.

Another aspect of the infrastructure is how it deals with sediment transport and passing of floating debris. Different types and configurations of division structures have different capacities to pass on sediment load and debris. Processes of scouring and sedimentation of the canals influence water distribution. Division of water flows at bifurcation points is influenced by sediment deposition (and scouring) of the upstream and downstream canal stretches, and also debris that gets stuck in a gate changes the water division. Differences in passing of sediment load not only influence water delivery, but also the maintenance needed for cleaning out certain stretches of canals (Bos 1978, Méndez 1998).

To predict the propagation of fluctuations in an open canal system with upstream control the Hydraulic Flexibility (F) of the bifurcation points is calculated. Bos (1978), Van der Zaag (1992), Horst (1998) and Van Halsema and Murray-Rust (1999) use the concept of Hydraulic Flexibility introduced by Crump (1922). F is the ratio between the Sensitivity (S) of the offtaking and ongoing structures. S is the change in discharge divided by the initial flow through a structure (or canal) caused by a unit rise of the upstream head. At $F = 1$ all flows in downstream canals at a division change proportionally to any change in the upstream flow. At $F > 1$ the offtaking canal takes most of the change in upstream water flow. At $F < 1$ the ongoing canal takes most of the change in the upstream water flow. However, Hydraulic Flexibility is not a static property of a bifurcation point, F depends on upstream (and in non-modular situations also downstream) water levels.

If in an irrigation system all bifurcation points are of the same configuration the Hydraulic Flexibility determines how flow changes are propagated through the system. At $F = 1$ the fluctuations are propagated proportionally through the system; for $F > 1$ the fluctuations are mostly propagated to the head-end; and for $F < 1$ to the tail-end of the system.

Division structures have certain requirements for use. Pradhan (1996) and Horst (1998) suggest that fixed proportional weirs are preferable over adjustable undershot gates, because proportional division structures are more tamper-proof and more transparent (farmers can see how much water flows through them). Horst furthermore suggests that gradually adjustable undershot gates should be avoided because they need relatively much and skilled personnel. Also Plusquellec *et al.* (1994) recommend specific types of division structures that are easier to operate. Horst, Plusquellec and others, however, do not look deeper into the relationship between structures and operators in actual performance. It appears that most authors regard the human element in the water distribution as a negative factor. Few describe the skills, motivation and pride of the operators, the services they deliver, and the decisive factor they play in running the systems. Also the users are mostly regarded as "irrigators that interfere in the main system" (Wade 1990).

5.2.4 Operators

Operators are here defined as any person contracted to operate division and check structures. Two aspects seem to be crucial to understand the performance of the operators: the means of coercion to induce good performance and the ability of the operator to perform well. Both should apply to guarantee at least no constraints from the side of the operation (the water availability, infrastructure and water users might still cause problems).

To analyse the coercion felt by the operator to work well we will look at coercion that comes from within the irrigation organisation (which can be a government agency or WUA) and coercion related to relationships with external actors. If we look at the external coercion we regard the agency or WUA as a company, the operator as an employee and the water user as a client. In the case the operator is contracted by the WUA the water users are both employers and clients. In that case it is clearer to see the elected farm leaders who are in the board of the WUA to be employers and the common water user as client.

Enforcement of the tasks the operators has to execute can come from the description of tasks in combination with the monitoring of it, and sanctions and/or rewards given accordingly. The amount of coercion is related to the possibility and amount of monitoring and the impact of the sanctions and/or rewards given to the operator. It helps if the users see the tasks of the operators as legitimate and the operator has certain authority to take decisions.

External coercion can come from clients (water users) or government bodies. The way the operators are held accountable for their work towards the water users is important. Accountability was defined in Chapter 1 as a power relation involving monitoring and enforcement of agreements. The operators (directly or via their employers) can be held accountable for the water delivery if institutions are in place that guarantee the delivery of certain volumes of water (against payment), in which case the client is protected against poor delivery. Water users might have other ways to enforce delivery of the water they are entitled to, for example: (threats of) violence against the operator, on-site protests, put pressure through news-media (local newspapers, radio or television), and elections of the board of the Water Users' Association. Government bodies, for example the local Ministry of Agriculture might monitor the performance directly or mediate in conflicts between the water users and the irrigation organisation. The government bodies might put rewards and sanctions according to their evaluation of the performance.

Besides coercion, the skills of the operator are important. In many irrigation systems in the world that provide flexible scheduling manually operated, gradually adjustable, vertical sliding gates are used. It is considered difficult to realise good performance with this type of structures. Plusquellec *et al.* (1994:46) call them '*specific structures to avoid*' as check structures and, as stated above, Pradhan (1996) and Horst (1998) also strongly advise not to use gradually adjustable sliding gates. Besides the authority and skills, the operators also often need keys or tools to operate the gates.

Only few studies address the actual practices of the operators in operating the division structures. Four studies show the capabilities of the operators: Van der Zaag (1992), Clemmens *et al.* (1994), Sloan (1997) and Godaliyadda *et al.* (1999)[2]. Van der Zaag (1992) stresses the practical knowledge the '*canalero*' (operator) in a middle-sized open canal irrigation system in Western Mexico has on the schedules, canals, hydraulic behaviour of the water in the canals, crops, fields and water users. He provides many insights in the behaviour, strategies, communication and negotiation skills and constraints of the *canalero*. From his work it becomes clear that the *canaleros* "*do not simply unthinkingly execute orders received from the engineers in the District's offices, [...] (they) interpret the guidelines received from above and adapt them to the varying needs and constraints found at field level*" (*ibid.*:76). Other issues which appeared to be important: the social pressure among the *canaleros*, the location (dependence) of the irrigated areas, capacity of the canals, the fact that *canaleros* act as 'policemen', threats of violence against the *canaleros* by the water users, and personal motivation (including pride) of the *canalero*.

The articles of Clemmens *et al.* (1994) and Sloan (1997) describe the Maricopa-Stanfield Irrigation & Drainage District (MSIDD) in Arizona. In 1990 the MSIDD tried to implement the automation of the operation of the 35 check gates in the 120 km long main canal. After failure of the automated operation, causing wide fluctuations in the water level, the field personnel took over the manual operation again. The computer system was then successfully

[2] To these studies can be added a novel written by Crawford (1988) who describes his life as a *Mayordomo* (ditch tender) of a small Farmer Managed Irrigation System (FMIS) in Northern New Mexico in the USA. This is clearly not a scientific work, but it is one of the few accounts put on paper by an actor in water distribution himself. Also Sloan (mentioned above) is a Water Master himself in the MSIDD system.

programmed following the daily routines in gate operation as developed and by trial-and-error process in the practices of the operation by the field personnel.

Godaliyadda *et al.* (1999) simulated different modes of co-ordination of operation of the manually operated gates in different open canal gravity systems in Sri Lanka. They show that the actually practiced co-ordination - the Time-Lag Operation - comes quite close to the optimal co-ordination that can be achieved with the existing control structures. Murray-Rust and Snellen (1993:62) provide the example of the fully gated Viejo Retamo irrigation system in Argentina that performed well: "*Water distribution equity under this system is extremely high (...). Almost all units show similar values for the ratio of intended to actual deliveries, and there is no noticeable tail-end effect. (...) a situation of near-perfect implementation of water allocation plans was achieved.*"

These examples from Mexico, Arizona, Sri Lanka and Argentina show the great ability of the operators (in Arizona even better than the computer) to control the water flows. By experience they know under different conditions how to change the gate settings to get the desired discharges and water levels.

5.2.5 Water users

Finally the water users themselves play a crucial role in the performance of the system. In three ways they might contribute to the good performance of the water delivery. First, by participating in the delivery and management. Second, by enforcing the accountability mechanisms discussed above. Third, by the mutual social control among the water users in the same tertiary block, but also between groups of users in different tertiary blocks. Of course, the water users might also interfere and obstruct good performance. Wade (1990), Mollinga (1998a) and Wahaj (2001) give several examples of individual and collective actions of water users in a large-scale irrigation system in India and Pakistan. Most prominent are searching for political support, tampering with the tertiary intake gate and re-arranging irrigation turns.

The degree to which accountability mechanisms are in place is already discussed above under the heading of the external coercion for the operators and the irrigation agency or board of the WUA. However, for the accountability to function well, the water users themselves should enforce the accountability mechanisms. This depends on the power relations between the users, operators and board of the WUA or agency. A higher degree of organisation of the users results in more collective action to put effective pressure on the operators and the agency or board members. The degree of organisation and overcoming of the free-rider problem (or prisoner's dilemma) has to do with social capital (Uphoff 1992). Also they should be able to monitor the performance. This again is related to the infrastructures (e.g. type of structures, measurement structures, and distances), the skills of the users and the informal rules established for co-operation.

Within the tertiary block the mutual social control among the water users is usually high. If they rotate water or if they split the flow between them, in either case it is clear that if some farmer takes more than (s)he is entitled to, one or more other farmers get less water. Because of the short spatial distances social control is possible. Whether or not deprived farmers can actually correct the water stealing and get their full share depends on social power relations. A small farmer might not be able to get her or his share if a large landowner is stealing her or his water. Also the water delivery schedule should be clear. Monitoring might not always be possible, for example at night.

A summary of the above presented framework can be seen in Figure 5.1. The three factors introduced are partly interchangeable between each other. The weakness of one can be compensated by the force of another factor.

Factors		**Indicators to check**
Physical infrastructure	Spatial layout of canals and drains	• Tree vs. hierarchical structure • Drains cross canals? • Length, slope and capacity of canals (scouring and silting)
	Water control structures	• Check structures in canals to control water level • Measurement structures
		• Division structures at bifurcation points • Adjustable or fixed • Hydraulic Flexibility (F) • Tamper proof / robust • Transparency • Passing of sediment load (bed load, suspended load, wash load, and floating debris)
Operators	Coercion to work well	Internal to the irrigation organisation: • Tasks and authorities • Pride, satisfaction with work, payment, job challenges • Monitoring and enforcement by rewards and sanctions (incl. informal regulations, corruption, etc.)
		External to the organisation: • Accountability towards users via elections, service agreements (incl. compensation in case of poor performance), fee payment, sanctions, protests, (threats of) violence • Direct government control by monitoring and rewards and sanctions
	Skills to operate well	• Ability to regulate gates and predict hydraulic behaviour of the system and foresee the water demand of the water users, and their behaviour in tampering and water stealing • Ability to negotiate with overseers and water users
Water users	Participation in actual delivery and in management	• Individual labour input in the distribution of water • Degree to which water users can have influence on decisions on personnel and location of structures
	Enforcement of accountability mechanisms	• Degree of organisation (social capital) to enforce accountability of irrigation organisation • Skills and opportunities to monitor performance (transparency of operation, information on: schedule, flows and measurements)
	Mutual social control	• Social power differences between the water users and organisation • Interests and ability to monitor

Figure 5.1: A framework to analyse most important factors in delivery of irrigation water in large-scale irrigation systems

5.3 Operation and assessment of water delivery performance in Chancay-Lambayeque

Before looking at the delivery performance we should first look at the Relative Water Supply (RWS). The RWS in Chancay-Lambayeque in the irrigation season 1998-1999 was: 0.8 at field level, implying moderate water scarcity. In dry years in Chancay-Lambayeque RWS can be as low as 0.6 at field level. (Calculated on the basis of Table 3.5, taking 1998-1999 as a wet year.)

5.3.1 Main system

In Chapter 3 the layout of the canal system of Chancay-Lambayeque was presented. Only at three points in the 56 km long main canal Taymi were there check structures. These check structures were manually-operated, undershot, vertical sliding gates, with side overflow weirs. The main canal functioned like a reservoir to increase stability of the delivered flows and to provide extra water in case of sudden increased deliveries to the tail-end secondary canals. Lag time from the intake of the main canal to the last secondary canal was about 12 hours. Measurement structures at the beginning of most secondary canals were Parshall flumes.

The gate settings of the check structures and offtakes from the main canal were determined by the head engineer (*gerente*) of ETECOM S.A. He gave orders to the *tomeros* of the gates of the intakes of the secondary canals and the three cross regulators. As the lag time was 12 hours he used the main canal as a buffer. The intake of the main canal was not being measured. Its regulation depended on the deliveries to the secondary canals. If all secondary canals would receive the programmed flow, the main intake of the main canal was adjusted so that the water level of the last part of the main canal was more or less constant.

The structure of the layout of the canals was more in the shape of a tree than a hierarchical order, although both patterns could be seen. The crossing of the irrigation canals with the drainage canals by means of aqueducts did not pose a problem for operation in normal years. Only with the floods in the El Niño year 1998 about half of the aqueducts got damaged or destroyed, cutting off whole areas of irrigation water. After the floods it took more than a year to reconstruct and repair some of the damaged aqueducts. No stealing of water by means of damaging of aqueducts was observed, to carry the water in the drains to be used in the dry tail-end (as reported by Oorthuizen (1998) in the Philippines).

The capacities of the canals were sufficient during most part of the irrigation season. Only at the beginning of the rice season did the main canal not have sufficient capacity to let all farmers start at the same time. This was resolved, as explained in Chapter 4, by dividing the irrigated area into two parts, one starting to irrigate two weeks after the other.

The allocation to each secondary canal might change several times per day. Hence, gate settings of the manually operated vertical gates were changed constantly by *tomeros* of ETECOM S.A.[3] Communication between the *gerente* of ETECOM and the *tomeros* was

[3] The engineer of the *Junta de Usuarios* is not involved in the daily distribution. The staff of the *Junta* supervises ETECOM, and is involved much more in 'emergency' matters like break down of canals, special construction and maintenance works, and conflict management.

mostly by radio. The *gerente* would drive himself at least one time every day along the complete main canal to check the offtakes and water levels.

In Chancay-Lambayeque the performance of the delivery to two secondary canals was assessed. In Figure 5.2 the results of measurements are compared with the programmed flow to the San José secondary canal in the period from February 1st to April 15th 1999. As could be seen in Figure 4.1 this was a relatively water abundant period. San José is a secondary canal more or less in the middle reach of the scheme. It can be noticed that the actual flow was below the target level only in some ten days (out of 74), of which only one day had a severe drop in Delivery Performance Ratio (DPR). It can also be noticed that the programmed flow was set every day according to the number of water turns requested by the farmers. The DPR of the total observed period was 1.03, meaning that from February 1st to April 15th the ETECOM distributed 3% more water than scheduled to San José secondary canal. The DPR for the observed period was remarkably close to unity. The average of the daily DPRs was 1.049. The standard deviation (sd) of the daily DPRs was 0.161, implying that (presuming a normal statistical distribution) for each day the chance was 95 percent to have a DPR between 0.73 and 1.37.

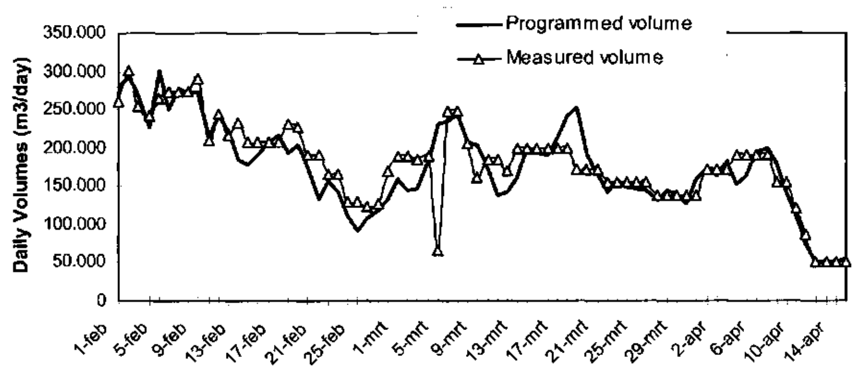


Figure 5.2: Programmed and measured volumes delivered to the secondary canal San José in the *Comisión de Regantes* Lambayeque in the period from February 1st to April 15th 1999. (Source: CR Lambayeque daily four measurements with current meter, and programming according to daily water requests of the users in the command area of the canal)

Figure 5.3 shows the programmed and delivered flow to the CR Muy Finca from January 2nd to 13th 2000. This was a relatively water scarce period as the river was below expected level of discharge and the Tinajones reservoir was almost empty[4]. As can be seen in Figure 5.3 the actual flow in the tail-end of the system is hard to stabilise in a water scarce period. Because in the main canal $F < 1$, all fluctuations are passed on to Muy Finca, which is situated in the tail-end of the Taymi main canal. Nevertheless, as can be seen for the days January 8 till 10 the operators could stabilise the flow. The average DPR is 0.963 and the sd was 0.150.

[4] From the figure itself it can also be seen that it was a water scarce period as only one change was made in the programmed flow. This means that the *Comisión* was receiving a fixed quota of water. In water abundant periods the programmed flow fluctuates much more as the programmed flow depends on the number of requested water turns of the water users (see for example Figure 5.2).

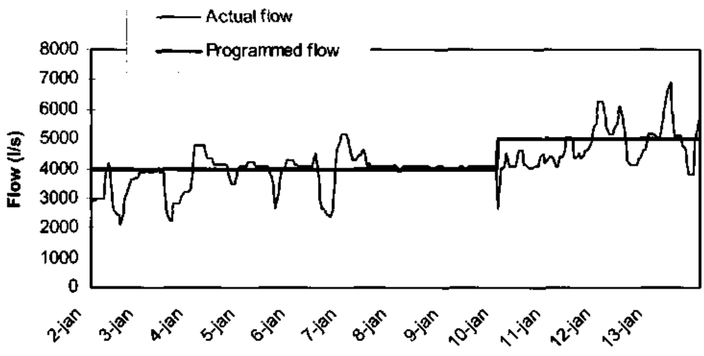


Figure 5.3: Comparing allocation and delivery to secondary canal in the CR Muy Finca in the tail-end of the Chancay-Lambayeque system in a water scarce period (source: measurements every hour from 2 to 13 January 2000 in Parshall flume, programmed flow according to field personnel)

In non-water scarce periods the DPR was higher: then the actual flow was almost always higher than the programmed flow, because normally the ETECOM released some ten percent extra water above the strictly needed flow to compensate for unexpected failures. This extra water normally entered tail-end canals of CR Muy Finca and was used there to deliver extra water turns.

5.3.2 Water delivery along the secondary canals

From the main canal Taymi several secondary canals branch of the supply water to the Subsectors managed by the *Comisiones de Regantes*. As the canal layout is a 'tree structure' most secondary canals split up before they start to supply water to tertiary blocks. In this study secondary canals are defined as canals supplying water to tertiary blocks. Apart from the secondary canals branching of from the Taymi canal, some secondary canals take water directly from the river downstream of the intake of the Taymi canal. One *Comisión*, depending on its size, managed usually about three secondary canals. Each secondary canal has a length of 10 to 30 km and serves 5 to 10 tertiary blocks. Usually, a secondary canal was managed by one *sectorista* and one or two *tomeros*.

A particular feature of the secondary and tertiary canals in Chancay-Lambayeque was that most ran relatively deep. Normal 'full capacity' flow level was in most canals still below the level of the neighbouring fields. This made stealing of water directly from the canal impossible without a lifting device. To make the water flow into a field the water was headed up with wooden stop logs or a temporary bund in the canal.

As mentioned above, most check and division structures were manually operated vertical sliding gates. Figure 5.4 shows the three main configurations of bifurcation points.

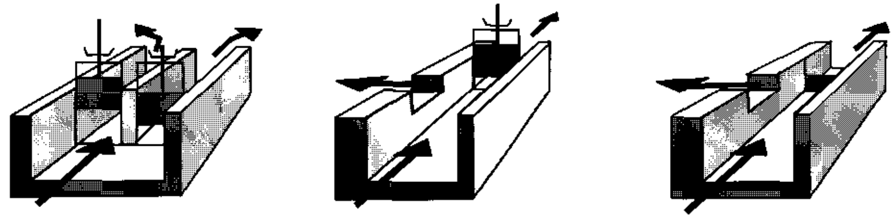


Figure 5.4: Three type of bifurcation points in Chancay-Lambayeque

A. *Level floor split*: a canal is split into two (sometimes three) canals. Each branch is of more or less equal size and the direction of the ongoing flows is more or less the same. The floors of the canals are at the same level. The discharge in each branch is regulated with a manually operated sliding gate (size of blade in range from 50x50cm to 200x150cm). Some of the structures have been in use for a very long time, others have been installed in recent years. $F \approx 1$. The actual F depends on the difference between the downstream water levels of the ongoing canals.
B. *Higher level offtake of smaller canal with sliding gate in ongoing canal*: (local name: '*Toma alta*' = high offtake) if along a main canal a smaller canal takes off, the level of the bottom of the offtaking canal is often situated 20 to 80 cm higher than the level of the ongoing canal. In some cases this means that the offtaking canal does not require a gate, and water is taken only in when the water in the ongoing canal is headed up. Sometimes a sliding gate is installed in the offgoing canal. The heading up in the ongoing canal is done with a manually operated sliding gate. Sometimes this gate in the ongoing canal has side overflow weirs. $F > 1$.
C. *Higher level offtake of smaller canal with timber logs in ongoing canal*: the heading up is done with timber logs to be fixed in concrete posts. The ongoing canal can be blocked completely or water can be flowing over the check structure. Sometimes the check structure is made out of wooden poles and sealed with earth clumps. This is probably the type of division structure used in the Moche and Inca periods in the secondary and tertiary canals. F can be bigger or smaller than 1 depending on the level of the bottom of the offtaking canal relative to the crest height of the weir in the ongoing canal. If the height of the crest is much higher than the bottom of the canal, $F < 1$. If the bottom of the offtaking canal is near or higher than the crest, $F > 1$.

Most bifurcations in the main canal were of type A (or only an offtake with a sliding gate without a check structure in the main canal). In the secondary canals the offtakes to the tertiary canals were mostly of type B and sometimes type A. The regulation of water within the tertiary blocks was mostly with structures of type C. Sometimes also type A and B structures were constructed.

Most of the division works were in good operational condition. The structures were not tamper-proof. Every day the *sectorista* had to check if the gates were tampered with: for example, the padlocks broken or a banana tree trunk stuck under a gate. Also the water users who had a water turn checked the gates to see if they were deprived of a part of their water.

The underflow gates were not transparent in operation. The actual discharge depended on the opening, and the upstream and downstream water levels. Farmers as well as *sectoristas* put marks in the canal bank at certain water levels as reference points of certain target water levels (which were directly related to discharges, they believed). Because of vegetation growth and sediment disposition in the canals during the season, the water depth was reduced with reference to the marks along the banks of the canal, decreasing the discharge related to this mark.

The operators (*sectoristas* and *tomeros*) were employed by the *Comisiónes de Regantes*, and were always male. They had clear tasks and mandates. They received no formal training in canal operation, although some were '*técnicos*' meaning that they had finished lower technical education. They learned the job on the spot. Normally an operator stayed in function for a period of 10 to 20 years, although some were fired, or found a better paid job elsewhere. The job of *sectorista* was not regarded as a heavy job, but working hours were from early in the morning to sometimes late in the afternoon, seven days a week during the irrigation season. Part of the day the *sectorista* spent on his motorbike riding along the canals, the other part of the day the *sectorista* had to do administrative tasks. The *tomero* lived near the gate. The *tomero* had the task to change the gates according to instructions from the *sectorista,* to remove debris blocking gates, and to register water flows at certain measurement points. At the beginning of many secondary canals Parshall flumes were constructed. Most were still functioning well and used on a daily basis. The tasks of the *tomero* were light, not taking much energy or time. The only big constraint of the job was that the *tomero* was obliged to be present at the gate 24 hours a day. He was only allowed to leave for brief periods or if he had arranged a replacement.

As regular jobs were hard to find and illegal revenues could be obtained from the position of operator it was a desirable job. Some operators were paid the full twelve months, others were only paid during the main irrigation season from November to June. A new operator was normally recruited from the pool of friends of the *presidente* of the *Comisión*, *Junta* or chief engineer of the ETECOM.

The *sectoristas* drew up the delivery schedule every morning according to the water availability and number of hours of water bought by the water users. They set the gates and gave instructions to the *tomeros* to maintain certain discharges or change gate settings at certain hours. The rules on tasks, salary and authority of the operators are all informal. In the *estatutos* no word is mentioned regarding the personnel of the *Comisiones*. Hence, there were also no official rules on rewards or sanctions from the board of the *Comisión de Regantes* regarding the work of the operators. Nevertheless, the board and the operators knew quite well what the responsibilities and rewards of the operators were. Also the board had an effective monitoring system, because water users would complain to the board if they felt the operators were not doing their job well. If the board felt too many complaints were filed against one of the operators, his contract might not be renewed the next irrigation season. The board maintained this high degree of accountability towards the users because the members of the board were very much interested to stay in their positions in coming elections of the boards of the *Comisiones*. Fear of losing the job was a strong 'incentive' for the operators to perform as well as they could. This fear was, however, not the only mainspring for the operators to work well, they also felt proud about their job. They felt it was a job with important responsibilities. They felt proud if for example the engineer of the ETECOM asked their opinion about hydraulic behaviour of a division structure, and rewarded their experiences by giving them tasks with special responsibilities.

The fear of the operators to lose their job if farmers complained too much to the board of the *Comisión* functioned only if farmers did complain. This formed part of the 'external coercion'. For water users it was clear what their rights were, it was clear to them that the bought volume of water should be available at the intake of the tertiary block during the scheduled time. If the water was not delivered in the right amount at the scheduled time the water users would first go to the *tomero* or *sectorista* to complain and ask for compensation. The operator would then go and check if the farmer was right in asking for compensation (sometimes they already knew not sufficient water had been available due to problems upstream of the intake). If the water user had been right, free hours would be scheduled the next day to compensate for the non-delivered volume.

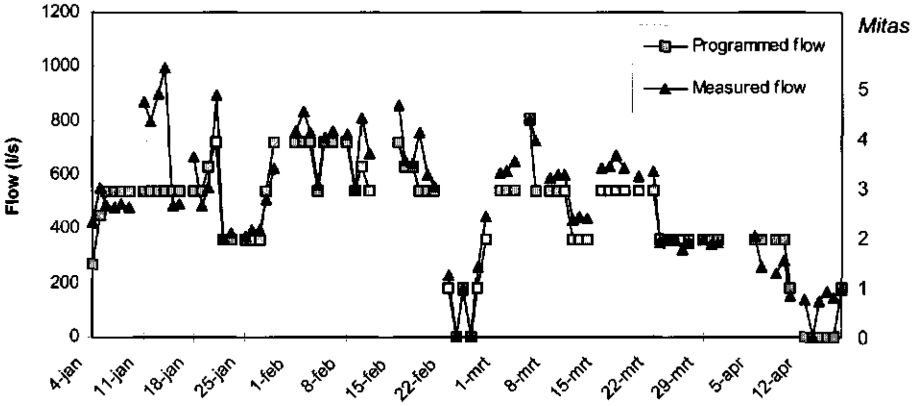


Figure 5.5: Comparing allocation and delivery to tertiary unit La Ladrillera & La Colorada in *Comisión de Regantes* Chancay-Lambayeque (source: daily measurements from January 4 to April 19, 1999, programmed according to official schedule)

Figure 5.5 shows the results from 81 measurements taken each morning at the intake of the tertiary block called 'La Ladrillera & La Colorada'. This intake is situated in the head-end of the San José secondary canal. The measurements were done from 4st of January to 19th of April 1999, this was a relatively water abundant period. As can be seen from the figure the performance was rather good: the measured values followed quite well the programmed flows. The largest differences occurred during four days in January: significantly more water was delivered than programmed (a suspicious view on this would be that the operators then had not yet adapted their water delivery to our measurement programme, and later did. However, that could not be proved). The average daily DPR was 1.10 and the sd was 0.21. It can be seen clearly from the figure that the number of '*mitas*' programmed to be distributed at the same time to the tertiary block often changed several times a week (and reached from 0 to 4.5).

To interpret the data from Figure 5.5 further, an important aspect is to analyse the Hydraulic Flexibility of the actual configuration of canals and gates. Figure 5.6 shows a simplification of the canal network of secondary canal San José in CR Lambayeque.

The arrows represent the offtakes with the highest Sensitivity (S). Thus, the offtake with an arrow would 'suffer' most from a decrease (but also gain most from an increase) of the upstream water level. It can be noted that the San José secondary canal and the La Ladrillera & La Colorada tertiary block occupy a relative 'vulnerable' position. If we look then again at Figure 5.5 it is all the more surprising that the DPR was so close to 1.0.

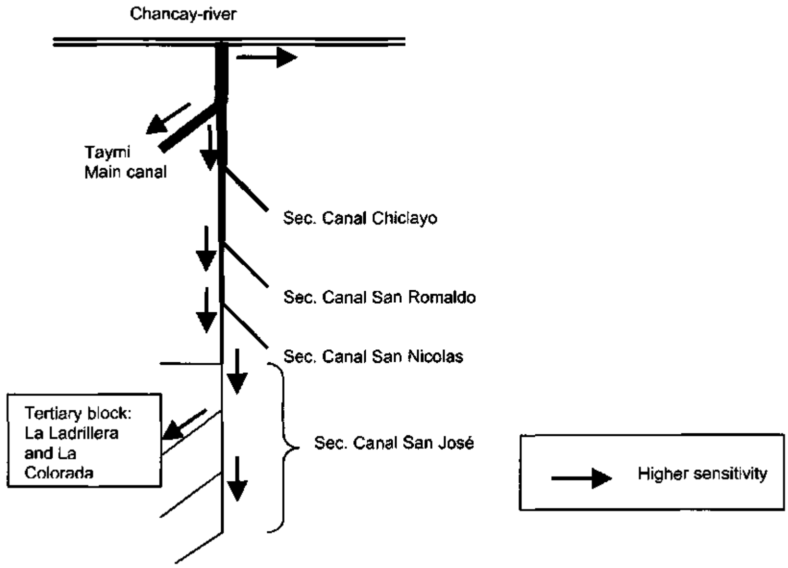


Figure 5.6: Graphic representation of the analysis of the Hydraulic Flexibility of the San José secondary canal and La Ladrillera & La Colorada tertiary block in *Comisión de Regantes* Lambayeque

The other tertiary canal observed in this study was the Sialupe-Sodecape canal in tail-end subsector Muy Finca. This tertiary canal has an undershot intake and is located halfway along the Heredia secondary canal. Here the average DPR was also very close to 1.0 (1.06), but nevertheless there were more fluctuations: some days with much more, and other days with much less water than programmed (sd = 0.44). In Appendix IV the data and some analyses of water delivery in Muy Finca are presented. Boss (1996) found similar water deliveries (n = 39) in CR Sasape during irrigation season 1995-96.

An important finding of the research was that the operators were very skilled in operating the vertical sliding gates. As described by Van der Zaag (1992), Sloan (1997) and Godaliyadda (1999), the operators use their experience rather than formal hydraulic knowledge to operate gates. The authors show that the precision of attained discharges and stability of flows is much higher than expected by Plusquellec *et al.* (1994) and Horst (1998).

Unscheduled flow changes were mostly negative (thus actual flow was less than planned). The negative flow changes occurred because an upstream gate was opened illegally and/or without warning the downstream operator. Negative flow changes also occurred because of blocking of an underflow gate of a check structure by floating debris (sometimes put there on purpose by a water user to get more water to his/her field). When the reservoir was empty and the river flow was relatively low compared to the expected river flow, the daily discharge fluctuations in the river could also cause positive or negative flow changes in the system. Scheduled flow changes were communicated to the *sectoristas* by the *jefe de operaciones*, with sufficient anticipation (usually one day).

The operators in Chancay-Lambayeque used a sort of 'manual feedback loop' to adjust and readjust gate settings. The *sectoristas* regarded their secondary canal as a closed system. The *sectorista* received a certain volume of water from the main canal. He knew how much flowed in by reading the Parshall flume or by means of a current meter flow measurement. This water had to be distributed over the tertiary canals and there were seepage losses. For example, the *sectorista* of secondary canal San José would receive 2,000 l/s to distribute to six tertiary canals, two taking one '*mita*' of 180 l/s and four taking each two '*mitas*' of 180 l/s (thus taking 25 % as lost by percolation from the canals). The incoming flow of 2,000 l/s was measured at the intake of the San José canal, but inside the secondary canal no further measurement structures were present. The *sectorista* would regulate the sliding gates at the six intakes of the tertiary canals '*al ojo*' (estimating the flows by the water levels vis-à-vis certain marks on the canal banks). As was shown above the division structures were not of the same type. The operators knew which intake would suffer most when not sufficient water was coming into his secondary canal or one or more tertiary canals took too much water.

For example, the intake of the tertiary block 'La Ladrillera & La Colorada' along the San José secondary canal was the first to suffer from an unscheduled negative flow change from the main canal (see Figure 5.6). The *sectorista* and water users referred to this intake as a '*toma alta*'. The *sectorista* checked this canal first. If there was not sufficient water flowing in, he closed one or more other tertiary canals a little, until the target discharge of the most 'sensitive' tertiary canal was met. He also checked if he did not put too little water in the tertiary canals by checking any overflow or too much discharge in the offtakes of the tertiary canal most sensitive to too much water.

Usually the operators used the water levels (they put little twigs in the earthen canal banks) and counted the screw threads of the gate as references to the setting of the gates (see Photo 5.1). They would use rules of the thumb like 'with gate X you need 3 screw threads to increase the flow with 80 l/s if the upstream water level is at Y'. This was a very rough estimation and they ignored the backwater effect caused by the sediment disposition and weed growth during the irrigation season and the heading up of water by water users along the tertiary canals. They overcame these problems by checking the complaints of water users if too little water arrived at their fields. This made the operation of the gates a trial-end-error process with a back-loop control: the target was delivering a certain volume of water at field level. The gate settings were adjusted and re-adjusted to match the flows to this target. Many years of experience with this trial-and-error feedback process made that the operators knew very well how to operate the gates to produce certain hydraulic behaviour.

During the flow measurement programme in La Ladrillera & La Colorada and Sialupe-Solecape it was found that about 10 percent (45 out of 417 measurements at field level) of the observed 'water turns' had not been programmed officially. These 'illegal' water turns were locally called '*riegos volantes*' (literally 'flying water turns'). These illegal water turns were different from water stealing where normally only flows of less than 50 l/s are involved. The *riegos volantes* look like normal turns in the field because the flows would be around 160 l/s at field level. However, the *riegos volantes* were not officially programmed and thus not officially paid for.

Photo 5.1: Operator counting screw threads of a sliding gate to estimate the water flow

The *sectoristas* could distribute these non-programmed water turns by 'generating' extra water. They had three ways of 'generating' more water. First was to distribute less than 160 l/s to the officially programmed water turns. If a *sectorista* had scheduled ten *mitas* of 160 l/s each, and delivered only 145 l/s, he saved 10 times 15 l/s which makes up a new - illegal - *mita*. As the farmers could not measure exactly the water entering their field it was hard to tell the difference between 160 and 145 l/s. The *sectorista* could sell this extra *mita* at the normal price gaining (for example 20 hours - if 4 hours were needed to fill up canals - of US$ 2, makes) US$ 40 per 24 hours, which was much more than a normal day wage of US$ 3.

However, the water users knew this and were very keen on discovering extra water turns being delivered to the detriment of their own officially paid water turns[5]. A second way of getting more water was to have more water flowing in from the main canal than officially programmed or to have less than 25 percent percolation losses from the canals. In having more water it was more profitable for the *sectorista* to deliver a *riego volante* than to deliver water turns of more than 160 l/s to the officially programmed water turns. To get more water from the main canal, good relations with the *tomero* and chief engineer of ETECOM were necessary. A third way of getting more water was the use of water that still flowed in the canals after a shut down of a gate. This 'left over' of water in canals was locally called '*descuelgo*'. As many changes were made in gate settings, often 'volumes of left over water' in the canals could still be distributed to fields.

Another way of having more water to distribute than that officially paid for was to programme free hours that in fact do reach fields (see Chapter 4). Free hours should be given in principle

[5] It takes about one or two hours walking along the canals inside the tertiary block to know how many farmers are irrigating simultaneously. All farmers with an official turn should be able to show the receipt of their payment for the turn. The farmers who cannot show the receipt are receiving '*riegos volantes*' or stealing water. This inspection on number of turns was only done when farmers suspected illegal water to be sold to the disadvantage of their official turns. On discovery of illegal turns the farmers would go to the *presidente* of the *Comisión de Regantes* to complain. The *presidente* cannot publicly accept the illegal selling (although he personally might have a share in it). Upon repeated complaints the deprived water users will exert high pressure on the *presidente* to fire the *sectorista* (and/or *tomero*).

only to fill up canals[6], or compensate for non-delivery, but in practice it was hard to monitor if none of the water programmed as 'fill hours' did reach a field, or if hours given for compensation really compensated for water that had not reached a field. Waalewijn (2000) found that about fifty percent of the water programmed to fill up canals did reach the field (n = 17 canal fill-ups). This water could be sold illegally by the *sectorista* to the farmer. The operator could not just give the free turns at will. His supervisors (the board of the CR) would only accept free compensation turns if the delivery to the secondary canal was lower than programmed. Also the total number of free turns given in a year was an indicator for the performance of the *sectorista*: too many free turns meant he had not been operating well. All these data were available for monitoring by the board because the actual flows and programmed water turns were recorded in the computers of ETECOM. On request the administration of ETECOM produced helpful overviews with the SARA computer-programme according to the wishes of the board. This was an important issue because *sectoristas* could make a lot of illicit money by selling water turns to farmers and register them as free compensation turns. It was most probable that the money made by the *sectorista* traveled partly up to higher regions: first to the *presidente* of the *Comisión*, then to the *presidente* of the *Junta*, and who knows even higher (in a similar way as found in India by Wade (1982), however, there where no indications that posts in the *Comisiones* could be bought).

It is important to realise that the 'perverse incentives' for the *sectorista* to sell water illegally can improve the water delivery performance. As the benefits from illegal water selling are very high compared to his salary, the *sectorista* will work hard to minimise the losses for filling of canals needed for the delivery of water turns. In addition, all unscheduled water entering the secondary canal will be used, and will not be lost in a drain. Also, water still flowing in canals after the intake of that canal has been shut will be used if possible. This together with the intense monitoring of the water users of their own water deliveries leads to a high delivery performance.

If a group of farmers over a certain period of time had the feeling that an operator was not doing well his job they might put pressure on the board of the *Comisión* to replace him. The official place to do this was the General Assembly held two times a year. However, normally the farmers did not wait until the Assembly. They might write a letter to the *presidente* of the board, or invade the office of the board with a group of farmers until they were attended by the *presidente*; or they might have asked for field inspection by the board; or they might have gone directly to the government ATDR. The ATDR would normally not intervene directly in such minor matters, but pressure from this side might help the farmers to settle the case. Violence was not part of the strategy. In some severe cases farmers might block roads along canals or break padlocks and/or damage gates to protest.

If the farmers complained too much, the board (fearing coming elections) might fire the *sectorista*, but giving too much weight to complaints from the water users would induce even more claims for extra water, making the system impossible to run. In the end the social power balance between the water users, *sectorista* and board of the *Comisión de Regantes* resulted in the pattern of water delivery performance found.

[6] Here the 'response time' from the analytical framework comes in. As the response time was mostly less than programmed, water to fill up canals reached the field and was used to irrigate.

5.3.3 Water delivery inside the tertiary blocks

The division structures inside the tertiary block were either manually operated adjustable underflow sliding gates (configurations of type B, sometimes type A) or wooden overflow stop logs (configuration type C). Officially inside the tertiary blocks also the *sectorista* or *tomero* set the gates. The water users themselves were responsible for bringing their irrigation water from the beginning of the tertiary canal to their fields. That prevented others from tampering with the gate settings and prevented direct water stealing.

Inside the tertiary blocks the water flow was handed over from one water user to the next water user in the schedule drawn up by the *sectorista*. As farmers paid for the exact number of hours they were very keen on starting their irrigation turn at the precise hour scheduled for their turn. They therefore went to the field of the water user irrigating before their turn with a watch and cut off the field flow and diverted the water in the direction of their field at the exact time of the start of their irrigation turn. In the field no problems were observed in the handing over of turns. Also socially powerful water users let their water turn be ended by less powerful water users at the exact time. It must however not be concluded that no problems occur, especially at night, when no other persons are around to put social pressure on the irrigating farmer to stop irrigating.

During the irrigation turn the water user had to bring the water from the intake of the tertiary canal to her or his field. This included constructing a temporary bund in the canal to head-up the water into the field, and check and recheck the tertiary canal and field canals for any obstructions or stealing of water. Normally two or three persons (hired or family labour) were busy with these activities. At night in water scarce periods even more persons were needed to guard the water.

In some tertiary blocks the water users had appointed a *repartidor*. This *repartidor* not only scheduled the water turns in the tertiary block (as described in section 4.4.1), but also took care of the water distribution inside the tertiary block. He did not start and end all water turns, but took care of the water division between the different parts of the tertiary block and checked the water entering the tertiary canal. Introduction of the *repartidor* was a major objective of the NGO IMAR Costa Norte. And although the *repartidores* in the five *Comités* installed by IMAR functioned quite well, the idea of the *repartidor* was not copied by other *Comités*. In a lot of other *Comités* the users had an informal, non-paid, arrangement where one user went to the office of the *Comisión* to request water turns for several water users and the *presidente* of the *Comité* would check the water entering the tertiary canal, and resolve disputes over water division.

In the field research in Chancay-Lambayeque 395 flow measurements were done at the field intakes of farm fields in two tertiary blocks from December 1998 to April 1999 to check if the intended 160 l/s were delivered at field level. The two tertiary blocks are 'La Ladrillera & La Colorada' in the head of the San José secondary canal in CR Lambayeque and the 'Sialupe-Solecape' block in the middle reach of the Heredia secondary canal in CR Muy Finca. As shown in Table 5.1 the average flows at field level were 148 l/s and 153 l/s as compared to the agreed flow of 160 l/s. We can regard this as a considerably good performances, taking into account this was a *toma alta* (La Ladrillera & La Colorada) and a tail-end situation (Sialupe-Solecape). The sd in La Ladrillera & La Colorada was 27 l/s and the sd in Sialupe-Sodecape was 46 l/s. This means that the farmers in Sialupe-Solecape had to deal with greater variations in flows at field level than the farmers in La Ladrillera & La Colorada. As can be seen also from Table 5.1 the fluctuations at field level were directly related to the fluctuations in the secondary canal, because the standard deviation of the DPR of the delivery from the secondary canal to the tertiary block was twice as high in Muy Finca compared with Lambayeque.

Table 5.1: Results of flow measurement programme from December 1998 to April 1999 in two secondary canals and two tertiary blocks (source: own measurement programme)

Tertiary block	**La Ladrillera & La Colorada**	**Sialupe-Sodecape**
Size of tertiary block (ha)	568	767
Number of plots	141	157
Average DPR at intake of tertiary block[1]	1.08	1.04
Standard deviation of DPR at intake of tertiary block[1]	0.16	0.47
Average flow to field inside tertiary block (l/s)	148	153
Standard deviation of flow to field inside tertiary block (l/s)	27	46

1. The intake measurements are compared only for the period 1 February - 17 April 1999 (see also Figure 5.5 and Appendix IV).

For further analyses the flow measurements were grouped according to location in the tertiary block (Table 5.2) and according to landholding size (Table 5.3). As was expected the delivery decreased going from head to tail-end. This was caused by seepage losses in the tertiary canal, and water stealing - including the unequal split of water inside the tertiary block - by fellow water users, which was more probable the longer the water had to travel in the tertiary canals. It was expected that bigger landowners would be able to get more water. This was only partially found: the biggest landowners received the lowest flows. Probably because they hired out the labour of surveying the canals, while small and middle-sized holders would do this important work themselves.

Table 5.2: Average flows at field intake in two tertiary blocks, according position (N=395)

Location	**Number of farm plots**	**Average flow (l/s)**
Head end	82	168
Middle	124	153
Tail end	81	145
Total	287	152

Table 5.3: Average flows at field intake in two tertiary blocks, according to land size (N=395)

Landholding size (ha)	**Number of farm plots**	**Average flow (l/s)**
0-3	63	145
3-10	204	156
10 +	20	142
Total	287	152

One can distinguish two possible causes for poor delivery to the plots: one is water theft inside the tertiary block. The other is low supply towards the tertiary block. A sudden decrease in the supply to the tertiary canal (without being programmed) is called a '*baja*' by the users.

Water stealing inside the tertiary block was undoubtedly the most frequently committed water-related offence occurring in the Chancay-Lambayeque system. In all tertiary blocks upstream water users would try to take water destined for downstream users. This might occur while the upstream user was having an official irrigation turn. In that case they tried to divert more water into their parcel than their share. Alternatively, they tried to steal water while they were not having a water turn. This could be done when water is flowing alongside their plot by making an opening in the earth bund of the parcel, so some water would flow into the field. Or, they constructed the 'tap' blocking the intake of their field in such a way that it would collapse under the water pressure from the canal, and thus water would flow into the field of the thief. Mostly flows of less than 50 l/s were involved in theft.

When the farmer who had the official turn discovered the taking of too much water by an upstream official water turn, or discovered an illegal intake, she or he might do: (1) nothing, (2) correct the illegal intake of water him or her self, or (3) complain to the stealing farmer. This last option would in most cases cause a quarrel. The stealing farmer would most probably claim to have had the right to take the water (s)he was taking. This does not mean that the stealing farmer actually was convinced that she or he had been entitled to this water. It must be seen much more as a 'decent' way to confront the situation: the upstream farmer was caught 'red-handed' and it would imply loss of face if (s)he would just simply have admitted to be violating the rules by stealing water. However, as the stealing farmer knew (s)he was not in the right, the situation would be settled in peace[7]. To give the stealing farmer a way out without more loss of face the downstream farmer would tell the stealing farmer to close the gate to her or his plot, and then walk further along the canal. Normally then, when the downstream farmer came back to the site of the stealing, after more canal inspection, the gate would be closed and nobody would be present at the site. It might also happen that the gate of the illegal intake had still not been closed but the stealing farmer had retreated. The downstream farmer could then close the illegal intake her or himself. By doing so the stealing farmer could take some more water illegally until the downstream farmer would come back to close the intake, and, more importantly, the stealing farmer could still pretend (s)he had been in her or his right and did not need to admit that (s)he had been stealing water.

All water users would inspect the complete watercourse upstream of their field intake during the complete period of the water turn. They themselves, or a relative or a hired peon would walk the stretch several times to close all illegal water intakes. The upstream water users knew very well the downstream water users and knew exactly what reactions their water stealing would provoke with each downstream water user. Some upstream water users attended the daily water scheduling at times when they knew very well they were not entitled to a water turn themselves. They just came to hear whom of the downstream water users would have a water turn and at what time to know when to steal water. Some downstream water users were known to be lazy and were not expected to inspect the upstream water intakes at night. Others were known to be 'drunks' and were expected to be drunk when having a water turn on Sunday night (the weekly night many men in the rural areas drink their home brew alcoholic drinks until dawn).

Although this typical way of stealing water was attempted during many official water turns being delivered to the downstream parts of the tertiary block, it must be stressed that the water delivery inside the tertiary blocks was not an anonymous 'war of all against all'. In the end, only less than five percent of the water delivered to the tertiary blocks was being stolen directly by fellow farmers. Actually, the number of upstream farmers who could steal water while a particular downstream water user was having an official water turn was quite limited because of physical reasons. An upstream farmer could only steal water when the plot had an intake directly connected to the tertiary canal in which the water ran, and only if the water level was sufficiently high to flow into the plot without needing 'heading up'. Heading up the

[7] In rare cases the internal distribution of water in the tertiary block gave rise to hand-to-hand fights at the site of the water stealing. In most cases this happened when one, or both, water users were drunk. However, during the field study period this was only once seen and only seldom heard of. No weapons or organised threats were used.

water to steal would be a too obvious way of stealing, and because in most canals the water level at full capacity was below the field level, only in some particular stretches of each canal water stealing was possible. Downstream water users knew very well the owners of the plots along those sections. They knew exactly where to go to look for water stealing and how to behave when encountering a particular water user stealing water.

The mutual social control among the water users in the tertiary block was strong. A lot of labour was put in guarding the water during the water turn. As always, the social power differences among the farmers in the block were important. It was easier for a big landowner to steal from a small landowner without punishment than the other way around. However, as could also be seen from Table 5.3, the differences were not big. Small farmers had their own 'Weapons of the Weak' (Scott 1985) to struggle for the water they were entitled to. An example was that a group of small farmers in La Ladrillera once set fire to a young sugarcane field of a big landowner in the head-end of this tertiary block that had been repeatedly stealing part of their water. This revenge did not have the desired impact however, because during various field visits (especially at night-time) this upstream big water user was still stealing water. From this it becomes clear that the downstream water users do not normally simply accept water stealing, but will monitor and take action. However, if the head-end user is too socially powerful little can be done.

Very seldom the water users went to the *Comisión de Regantes* to complain about water stealing inside the tertiary block. The *Comisión,* but also the ATDR and AACH regarded the water distribution inside the tertiary block as the responsibility of the water user who had the official turn[8]. An exception was the splitting up of the water stream inside the tertiary block to serve different '*mitas*'. This split had to be regulated by the *sectorista* and *tomero*. In practice however, the splits were often set and regulated by the water users themselves and often tampered with. Normally the water users just corrected and re-regulated the gate settings and only asked for assistance of the *sectorista* or *tomero* when they thought this was really necessary and would lead to stopping of tampering. In practice, the *sectorista* or *tomero* would do little to prevent stealing of water by tampering of the division structures within the tertiary block. Only when a water user broke a padlock there was 'hard' evidence. There are two reasons why the *sectoristas* could monitor and control the gates along the secondary canals, but could not prevent tampering of gates inside the tertiary blocks. First, because of their small number and easy access (all along the road along the secondary canal) the secondary canal structures could be visited once or twice a day. There are more structures inside the tertiary canals and they are less easy to reach from a road. Second, the monitoring by the users among themselves inside the tertiary block provides a much more effective means of preventing tampering than monitoring by the *sectorista*[9].

[8] The ATDR and AACH warned the users to carefully monitor the water delivery to their plot because if any water leaks (or flows) to another farmers' field this farmer might even file a case against the water user with the water turn for damage to the crops by too much water. According to the ATDR and AACH the water user with the official water turn is fully responsible for the delivery of the water to her or his field. If any other farmer takes water accidentally or by purpose it should be stopped by the water user with the official water turn. This rule prevents a lot of charges of water stealing from reaching the government agencies.

[9] The farmers' monitoring did apply much less to the structures in the secondary canal because they were located further away from the farmers' fields, and the farmers did not normally know how much water should flow in the ongoing canal, whereas they did normally know how many '*mitas*' were programmed to different parts of the tertiary canals.

Negative flow changes to the tertiary canals were locally referred to as '*bajas*'. These *bajas* can occur because of negative flow changes in the river or by unsteady flow caused by (un)programmed opening and closing of gates upstream of the tertiary canals. *Bajas* are very unpleasant for a farmer as they mean the farmer will receive less volume of water than paid for. The rule was that low flows would be compensated with free hours the next day, if the operator agrees that it was not the fault of the farmer that a less than programmed flow reached the field. Two problems, however, arise for the farmer: first the farmer has to be sure less than 160 l/s is entering the field. For a farmer the assessment of the actual delivered flow at field level is difficult. They normally only know how much the flow had been at the end of the irrigation turn, as for example it would take normally 3 hours to fill all basins up to a certain level and now, with the low flow only half of the basins had been filled after 3 hours. Secondly, it takes time to find the operator and to return to the intake. In the meantime the turn might have ended. Now nobody can prove anymore whether the discharge had been sufficient or not. Another problem was the measurement of the flow. In some cases the operator had a small current meter, but in most cases the operators would just estimate the flow and had to negotiate with the farmer standing at the intake to come to an agreed estimation of the flow. If the farmer did not agree (s)he would go to the board of the *Comisión* to complain. If the operator agreed there was a shortage in delivery he would programme a new water turn free of cost to the farmer the next day to compensate for the poor delivery.

The daily negotiation between the water users and the *sectorista* about whether or not the 160 l/s were delivered at field level took a lot of time and was not easy to understand for an outsider. The water users could not measure the flow exactly and in most cases the *sectorista* could not either. The water users always benefited by an increase of the flow or free water hours. The operator benefited by not giving free hours, as too many free hours given would make him suspect of illegal selling of free hours. In the end, it again boiled down to power relations. In this case power was related to the mobilising of support. For the *sectoristas* support could come from other staff and the members of the board of the *Comisiones*. If they provided back-up for the *sectoristas* the users could do little. The users could mobilise back-up by organising themselves and put pressure on the *sectoristas* and board.

5.4 Operation and assessment of water delivery performance in Jequetepeque

In Jequetepeque the Relative Water Supply (RWS) was higher than in Chancay-Lambayeque. In the irrigation season 1998-1999 the RWS at field level was 2.0, implying abundant water supply. In dry years in Jequetepeque RWS can go down to 1.3 at field level. (Calculated on bases of Table 3.5, taking 1998-1999 as a wet year.) This implies that precise water delivery is less important compared with water scarce Chancay-Lambayeque.

5.4.1 Main system

In Chapter 3 the layout of the canals in the Jequetepeque irrigation system was presented. The - German designed - main canal Talambo was lined and did not have check structures to regulate the water levels. The *Comisión de Regantes* Talambo constructed some provisional weirs in the Talambo canal to increase the water level to be able to take water in the first couple of offtakes.

Each Saturday the *gerente técnico* of the *Junta de Usuarios* set the water flows to each *Comisión de Regantes* in a meeting with all *jefes de operaciones* (see Chapter 4). The next Monday morning the gate settings of all secondary canals were set to take the water established by the *gerente técnico*. Under normal conditions the gate settings would not change until the next Monday.

In the beginning of the irrigation season, when the soils were not yet saturated, the gates were regulated quite strictly, and the secondary canals would take the water established by the *gerente* of the *Junta*. However, as the irrigation season unfolded, the soils would get more saturated and water would flow from drains and groundwater into the secondary canals. In the Guadalupe secondary canal, for example, more than one cubic metre per second would still flow at the end of the irrigation season even when the head-gate would be completely closed.

In Table 5.4 some measurements in secondary canals in Jequetepeque are shown. Of course the sample is very small, but at least the measurements sustain the impression from field observations and interviews that almost always more water flowed in the canals than programmed.

Table 5.4: Programmed and measured water flows to secondary canals in Jequetepeque

Comisión	Secondary canal	Date	Programmed (l/s)	Measured (l/s)	Difference
Guadalupe	Catalina-Milagro	04-01-99	2,300	3,000	+ 30 %
Guadalupe	Catalina-Milagro	15-02-99	1,880	3,000	+ 60 %
Pacanga	Pacanga	23-11-99	1,800	2,100	+ 17 %
Chepén	Lurifaco	22-11-99	1,500	1,437	- 4 %
Chepén	Chepén alto	22-11-99	330	408	+ 24 %
Chepén	Cerio	22-11-99	270	307	+ 14 %

5.4.2 Water delivery along the secondary canals

In Jequetepeque many more division structures were found of type A: 'Level floor split' (Figure 5.4) compared with Chancay-Lambayeque. Two or more underflow sliding gates split up the flow more or less proportionally; the proportions depending on the gate settings. This can be explained by the fact that in Jequetepeque the mode of water distribution inside the *Comisiones* was continuous flow, with flows more or less proportional to the area irrigated. However also bifurcation points of type B were found.

The engineer of the *Comisión* (*jefe de operaciones*) and the ditch riders (called '*canaleros*' and not *sectoristas* as in Chancay) had less work than in Chancay-Lambayeque. Three reasons for this difference were: the area and number of water users per *Comisión* on average were only half that served per *Comisión* in Chancay (see Tables 3.2 and 3.3). In Jequetepeque no individual water turns had to be scheduled every day (except for the first irrigation turns and the few non-rice areas). The water distribution did not follow a complicated and precise schedule based on on-request turns, but rather is a continuous flow normally only requiring changes in gate settings once a week.

To actually distribute the water in the secondary canals the *canaleros* used a system similar to the 'manual feedback loop'-system used by the *sectoristas* in Chancay-Lambayeque. The *canalero* knew how much water was assigned to each secondary canal under his supervision.

In some *Comisiones* a Parshall flume was constructed[10] at the intake of the secondary canals. In other *Comisiones* personnel of OPEMA came each Monday to measure the flow to check whether the flow actually distributed was the flow assigned to the *Comisión*. The *canalero* would see to it that in principle each '*campo*' would get its share from this flow proportional to its area (depending also on the crop). A *campo* can be regarded as a tertiary block, but *campos* were smaller than the tertiary blocks in Chancay-Lambayeque and not all had a direct intake from a secondary canal. It was noted during field observations and flow measurements that the area-proportionality was often not respected. This had several reasons. The *canalero* compensated for soil type: if a *campo* was known to have more sandy soils, relatively more water would be given to compensate for higher percolation losses. Water distribution would also be adapted to farmers wishes as explained in Chapter 4. Another reason for diverting less water to a certain *campo* was the amount of water the *campo* received directly from upsteam *campos,* via so called '*desaguaderos*'. *Desaguaderos* were a sort of drain in which a *campo* collected the water flowing out of the paddy fields. This water was 'recycled' in the next downstream *campo*.

In Table 5.5 some measurements are presented to compare the actual discharges to tertiary canals with the programmed flows. Also here the measurements confirm the idea that generally more water flows in the canals than programmed. Again, this is only a very small sample, but during conversations and observations the general picture of 'abundant' flows was confirmed.

Table 5.5: Programmed and measured water flows to tertiary canals in Jequetepeque.

Comisión	Tertiary canal	Date	Programmed (l/s)	Measured (l/s)	Difference
Guadalupe	Farfancillo	11-01-99	400	900	+ 125 %
Guadalupe	Farfancillo	15-02-99	450	800	+ 78 %
Guadalupe	Farfancillo	22-02-99	450	800	+ 78 %
Guadalupe	Farfancillo	01-03-99	360	600	+ 67 %
Guadalupe	Pueblo Viejo	22-02-99	150	340	+ 127 %
Guadalupe	El Mango	11-01-99	300	365	+ 22 %
Guadalupe	El Mango	15-02-99	300	300	0 %
Pacanga	Lucas Deza	22-10-99	250	373	+ 49 %
Pacanga	Montevideo	22-10-99	300	378	+ 26 %
Pacanga	Lucas Deza	23-11-99	120	157	+ 31 %
Pacanga	Montevideo	23-11-99	300	347	+ 16 %
Pacanga	Esquadra	23-11-99	300	261	- 13 %
Pacanga	Monteseco	23-11-99	300	468	+ 56 %

5.4.3 Water delivery inside the tertiary blocks

In Jequetepeque two modes of water distribution inside the tertiary blocks (or *campos*) were observed. The most prominent was continuous flow where several small water flows (± 1 l/s) would enter each rice field and small flows would also leave the field to flow into a next lower rice field or into a '*desaguadero*'. The small water flows would continue flowing 24 hours per day, all days of the rice irrigation season, except for days when fertiliser was

[10] Some Parshall flumes had been installed in 1968 before the land reform by the ATDR following from the Ley 17037 that introduced volumetric water allocation and payment in 1964. Other Parshall flumes were constructed more recently. Some flumes had gone out of function others were being reconstructed by the PSI project in 1999.

applied. Water level in the rice basins was regulated by adjusting the height of the crests of the openings in the bunds where the water would flow out of the basin.

The other mode was a system with water turns to individual fields. The rotation would be scheduled by the *canalero*. This mode of water delivery was much like the one described for Chancay-Lambayeque. This system was applied in the beginning of the rice season to give turns to establish seedbeds and turns for the first irrigation of the dry fields to start the wet land preparation and transplanting of the rice. Individual water turns were also scheduled for crops other than rice.

The above description of water distribution in a *Comisión* was observed in most *Comisiones* most of the time. However, in two *Comisiones,* and during brief periods also in other *Comisiones,* individual turns were also applied to rice fields. In the *Comisiones* San José and San Pedro they applied allocation, scheduling and charging per water turn much like in Chancay (see Chapter 6 for the reasons behind this). However, unlike in Chancay-Lambayeque, in San José and San Pedro the discipline in scheduling turns was much less: many free hours were scheduled and the actual water flows distributed were found to be much more than the programmed water flows. Water users were so used to the abundant water flows that in case the actual flow was according to the programmed flow paid for, the water users would complain the flows were much too small and would not accept the flows.

In the other *Comisiones*, where they applied continuous flow during the rice irrigation season sometimes also rotation was introduced. This was done in the case of water scarcity. Water scarcity because of low reservoir levels (and too much rice authorisation) was reported to have occurred only once in the past ten years. Water scarcity was introduced, however, also artificially to increase fee recovery (see Chapter 6).

5.5 Conclusions

The main purpose of this chapter was to analyse whether the distribution of the irrigation water was according to the planned schedule. Further, the assessment was used to scrutinise the infrastructure, the coercion experienced by the operators, the skills of the operators to deliver certain water flows, and the contribution of the water users to the operation of the system.

The performance parameters like Relative Water Supply (RWS) and Delivery Performance Ratio (DPR) were used to understand, in a more quantitative way, the severity of the water scarcity and to assess the actual delivery at some points in the system. This information was further used to understand the complex relations between the physical infrastructure, the water, the operators and the users. The analysis of the Sensitivity and Hydraulic Flexibility were used to understand better the hydraulic behaviour of the system and to select relatively sensitive offtakes for the evaluation of the delivery.

The Chancay-Lambayeque irrigation system had on average a delicate balance between supply and demand. In normal years the crop water requirements of the officially allowed crops can hardly be met (RWS of 0.8 at field level). In dry years severe water stress occurs (RWS of 0.6). Water turns were scheduled on request and paid a day in advance. This made the need for good performance high. From the flow measurements at the entrance of two secondary canals and two tertiary canals it was concluded that the delivery performance was high (average DPR very close to one).

The three main factors influencing this good performance were: the high degree of accountability of the *Comisiones* towards the water users; the skills and experiences of the operators to deal with the - difficult to operate - sliding gates; and the high degree of mutual social control among the water users. The main conclusion is that whereas authors such as Horst (1998) and Plusquellec *et al.* (1994) see the operator and water users (the human element) as 'disturbing' or at least limiting factors, in this study the operators and water users were not a negative factor. Rather, the human element proved to be a very positive factor, making the system function in spite of the difficulties posed by the water availability, complex on-request scheduling, difficult to operate hydraulic infrastructure, lack of measurement structures and low levels of training.

From the above it can be concluded that the water delivery performance at field level in Chancay-Lambayeque was so good (the 160 l/s is delivered at field level with only minor flaws), because of a complex of interacting factors. What is most outstanding among the findings is the fact that the *sectoristas* could make illegal money from delivering an extra water turn only if they managed to satisfy the water users that received official turns at the same time. The *sectorista* thus put in all his social and hydraulic knowledge and skills to deliver official turns of 150 l/s, which reaped extra water to sell illegally. Also by trying to have less than the 25 percent programmed percolation losses and use 'fill up water' (*descuelgo*) the *sectorista* could make extra water. The *sectorista* only had to be sure the water users did not complain too much about the 150 l/s instead of the 160 l/s they paid for. In this case 'perverse incentives' promoted good water delivery performance!

In Jequetepeque the need for good delivery performance was much less. The RWS was between 1.3 and 2.0 at field level. This implies a water abundant situation. However, also here the operators had skills to operate the gates well. Fewer conflicts arose over water distribution, but also in Jequetepeque the users claimed their water.

The different organisations in the hierarchy of water management all had different domains with different authority and duties. There was overlap of the domains, the interests at stake were high, and the knowledge of the stakeholders was partial. Thus, power relations between the water users, operators and the members of the boards of the *Comisiones* were as important to understanding the actual patterns of water delivery as an understanding of technical performance possibilities of the irrigation infrastructure.

6. The practices of volumetric charge setting, fee recovery and expenditure

6.1 Introduction

The setting, recovery and expenditure of Irrigation Service Fees (ISF) are at the heart of the discussion on Irrigation Management Transfer (IMT). The promoters of IMT consider it fair that users pay the costs made to deliver the water to them, and therewith lessen the financial burden of the government. Also they expect the water delivery service to improve because of the decentralised and 'market-like' relation between the water users and water provider. 'If you pay you can claim a good service'. A 'good' price would be a charge that raises sufficient money to operate and maintain the system well (e.g. Svendsen *et al.* 2000). Some argue that also amortisation of the initial construction costs and possible rehabilitation costs should be included in the charge (e.g. Perry 2001). Others put forward the danger that the Water Users' Associations (WUAs) will not raise sufficient money for maintenance and will neglect the long-term investments in the irrigation system (e.g. Vermillion and Sagardoy 1999). Again others are concerned with the poor farmers who may not be able to pay for the full costs of the services (Svendsen *et al.* 2000). Thus, some critics are in favour of some forms of subsidies to the irrigation sector.

Another discussion evolves around increasing technical water use efficiency by putting an incentive to save water by letting the users pay per volume of water used. A 'good' price would put a real incentive for the water users to increase the technical water application efficiency (Repetto 1986, FAO 1996, Perry 2001). Increasing technical water use efficiency is mainly useful if the water saved could be used elsewhere in the watershed and the seepage from the irrigated areas is not re-used. Putting a significant price per volume of water also makes it possible to let the water users take decisions on what crops to grow and how much water to apply reflecting the 'opportunity costs' of the use of water.

As explained in Chapter 1, volumetric fee recovery is regarded as very difficult in large-scale irrigation systems with many smallholders in low-income countries. It is difficult to meter and register the consumption of many smallholders in an open canal system. However, also recovery of flat fees per area poses many problems in irrigation systems.

If we put the concerns of these discussions together the main question for the two case studies would be if the ISF is set at a sufficient level and if the fee recovery is sufficient to guarantee the self-finance of the irrigation systems with sufficient long-term investments. Again we will look at domains, power to participate in decision-making, power relationships and accountability. The questions of the effect of pricing on water conservation by water users and the effect on livelihoods of (poor) farmers are addressed in Chapter 7.

This chapter highlights the way the ISF is set and its historic development. It evaluates the ISF recovery and the way the money is spent in (different levels of) the two irrigation systems. Finally it pays attention to the amount of subsidies received by the *Junta de Usuarios*.

6.2 Water charge setting

6.2.1 Irrigation service fee setting according to the water law

After the turnover process between 1989 and 1998 of the management of the irrigation systems from the ATDR to the *Comisiones de Regantes* and the *Junta de Usuarios* the irrigation systems were supposed to be self-financed by the water users. The Operation and Maintenance (O&M) costs of main and secondary levels would be completely covered by the *tarifa de agua* (water tariff) paid by the users. The 003-90-AG decree promulgated in 1990 established three components of the total *tarifa de agua* to be paid by the users:

I. *Componente Ingresos Junta de Usuarios* (component for both the *Junta* and the *Comisiones*); This part of the *tarifa de agua* is for the operation, conservation, maintenance and improvement of the irrigation infrastructure at main and secondary level. Also 5% should be paid to the ATDR. The amount to be raised depends on the annual budget set by the *Junta* and *Comisiones*. However, the decree sets a minimum cost per cubic metre of US$ 0.0085[1]. This is about three times the actual tariff charged in Chancay-Lambayeque and Jequetepeque. The General Assemblies of the *Comisiones de Regantes* decide on the annual budgets and thus the *tarifa de agua* per cubic metre. The ATDR approves the water tariff.

II. *Canon de Agua* (water tax); this is a water tax to be paid to the Special Project Bureaus, and is 10 percent of the *Componente Ingresos Junta de Usuarios*. The Decree 0048-91-AG establishes that the *Canon de Agua* is also used for financing the *Autoridad Autonoma* (AACH).

III. *Amortización* (amortisation of public works); either 10 percent of the *Componente Ingresos Junta de Usuarios* or an amount established by the Special Project bureau.

Besides the *tarifa de agua* the users might also agree in the General Assembly of the *Comisión de Regantes* to pay an extra fee for special works or activities. This extra fee is called a '*cuota*'. The users do not pay the tax and amortisation over the *cuota* as is done for the *tarifa de Agua*. The Water Law establishes that the *cuota* has to be paid per irrigated area. In this chapter the term Irrigation Service Fee (ISF) will be used to indicate the *tarifa de agua* together with the *cuota*.

In 1996 the Decree 001-96-AG-INRENA-DGAS the government allowed the *Junta* in Chancay-Lambayeque to use part of the *Componente Ingresos Junta de Usuarios*, but also the *Canon de Agua* and *Amortización* to finance their private company ETECOM S.A.

[1] The minimum water price is calculated as a percentage of the UIT (*Unidad Impositiva Tributaria*). The UIT is a standard amount used by the government to regulate all kinds of financial matters. The UIT increases each year with the same rate as the inflation. In 1998 the UIT was about US$ 850. Depending on the type of irrigation system the price of one cubic metre can be 0.0003 for non-regulated irrigation systems to 0.0010 percent of the UIT for regulated systems with reservoirs.

6.2.2 Water price setting in Chancay-Lambayeque

The history of the IMT process from 1989 to 1998 has been described in section 2.3.7. There it was explained that the *Junta* of Chancay-Lambayeque decided to opt for a volumetric ISF to increase fee recovery. Farmers were used to paying a small fee after the irrigation season. They opposed a charge per volume to be paid a day before the irrigation turn was delivered. However, the *Junta* managed to convince the water users that the charging per water turn would be necessary to raise funds for the repair of the main intake canal of the reservoir, which had become in danger of collapse. The majority of the water users seemed to have felt the volumetric charging was a legitimate measure of the *Junta*. The daily radio programme 'Voz del Usuario' of the *Junta* and IMAR Costa Norte and excursions for groups of farmers to the main infrastructure helped create this legitimacy. Furthermore, the *Junta* established a firm control over the water scheduling and delivery, in the sense that the *Junta* would only schedule and deliver water to a secondary canal the volume of water paid for in advance by the water users. In this way all water users were simply obliged to pay their *riegos* in advance, and the *Comisión* could not give water to water users that had not paid for a certain number of *riegos*. A water user recalled the cashier in the fee collection office in the *Comisión de Regantes* Lambayeque had said to him: *"I am sorry I cannot give you any water without prior payment, the computer of the Junta simply does not give water unless you pay the hours first..."* During the field study most water users interviewed stated their acceptance of the advance payment per *riego*. They saw the water turns as any other input, for example fertiliser, which you have to pay upon delivery according to the quantity you buy. The price set for each *riego* is much more an issue of discontent: most water users found the price for an hour of water too high and were in favour of cost reduction in the *Comisión* and *Junta*.

Each year in October the boards of all thirteen *Comisiones de Regantes* of Chancay-Lambayeque draw up an annual budget for the operation and maintenance costs of the next fiscal year[2]. In a meeting of the General Assembly the board presents the plans and corresponding budget to the assembled water users. The majority of the water users usually tries to block any increase of the spending, because they know that the ISF will increase with any increase of the budget. In the discussions between the board and the water users, the board explains that they needed more money for personnel and maintenance, while the water users stress that, due to the economic crisis, they are simply not able to pay more ISF. The water users assert that the *Comisión de Regantes* should try to do their work more effectively with the same money and that the wages of the operators are already high compared to the low earnings of the water users themselves. They are also usually opposed to buying of machinery for maintenance as they can do the maintenance with their own labour. To maintain the service at least at the level they had, the budget had to be increased somewhat to keep up with the inflation of about ten percent per year. In most cases the water users finally agreed with an increase of ten percent to compensate for the inflation. In other cases they did not approve any increase of the budget (see below).

The expenses planned in the annual budget have to be covered by the income from water selling and the extra '*cuota*' fee. Of the total fees raised by selling of water in a *Comisión de Regantes* only 34 percent went to that *Comisión de Regantes*. The rest stayed at the *Junta de Usuarios* to cover expenses in the main system and pay the tax and amortisation. This percentage was decided upon by the *Junta de Usuarios*. The General Assembly of each

[2] The fiscal year runs from January 1 to December 31. The irrigation-planning year runs from September to August. This can cause some problems with the fee recovery and financial balances.

Comisión de Regantes proposed a charge for a '*riego*'. As the *riego* is the charge to be paid for 576 m^3, and the total amount of water officially allocated to the *Comisión de Regantes* was known from the *Plan de Cultivos y Riego* (PCR), the total planned income from the sale of water could be calculated.

For example the *Comisión de Regantes* Muy Finca had a PCR for 6,451 ha (of which 3,649 ha cotton, 2,254 ha rice and 548 ha other crops). With the official water allocations per crop per hectare (*módulos*) it can be calculated that the total water allocation to Muy Finca for one year was 62 million cubic metres. This volume has hardly changed over the years, because the PCR was only modified slightly each year (see Chapter 4). If the water users proposed to pay US$ 2.00 per *riego*,[3] the total income from water selling could be US$ 215,000 of which the *Comisión* received 34 percent, or US$ 73,000. The total budget approved in 1999 was US$ 83,000. Thus US$ 10,000 had to be financed by means of the extra fee: '*cuota*'. The advantage of financing a part via *cuota* is that the *Comisión de Regantes* received the full 100 percent of the *cuota*. Thus, for the *Comisión de Regantes* the *cuota* are a means to increase their income without paying the 'taxes' to the *Junta de Usuarios*. For the *Junta de Usuarios* the *cuota* are a disadvantage, because they depend for their income on the sale of *riegos*. So a higher price of the *riego* means more income for them. Therefore, the *Junta de Usuarios* tries to restrict the part of the budget of the *Comisión de Regantes* that is covered with *cuota* instead of *tarifa de agua*. The *Junta* can do that by checking whether the *cuota* are only used for covering expenses for special investments and not the daily operation, as is defined by the water law. The *Junta de Usuarios* has the power to control the budgets of the *Comisiones de Regantes* because they receive the money of the *tarifa de agua* first, and then hand 34 percent over to the corresponding *Comisión de Regantes*. If the *Junta de Usuarios* does not agree with the budget they can hand over less (or no) funds.

The *cuota* was mostly a flat fee per hectare of between US$ 3 (Capote) and US$ 10 (Muy Finca). Sometimes also a small extra fee per *riego* was paid. Besides the fee per volume and this flat fee the water users also paid for the cleaning of the canals in their tertiary block. They could do that by providing labour or paying for a number of labour days according to the size of their landholding. In Table 6.1 the build-up of the total fees to be paid by a water user per hectare of rice in Muy Finca can be seen. This is only an average. A water user could buy less or more water and the ISF would decrease or increase correspondingly. Investments in inputs, labour and credit in one hectare of rice was about US$ 1,100 (Appendix III). The ISF is thus less than 5 percent of the total production costs.

As can be seen from Table 6.1 the *cuota* was relatively much more important than stipulated in the Water Law. For the *Comisiones*, which proposed the water prices, it was much more lucrative to charge *cuota* than *tarifa*, because they only received 34 percent of the US$ 28 and the full 100 percent of the US$ 12. It must also be noticed that the water user had more costs than just the US$ 49 to be able to irrigate. He or she also had to go to the *Comisión* to request and pay water turns (travel costs and time) and hire field workers to irrigate and guard the water along the tertiary watercourses.

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[3] In the text we will talk about the *riego* to have one price, eg. US$ 2.00, however, in practice the *Comisiones* make a difference between a *riego* scheduled for sugarcane and a *riego* delivered for any other crop. The price for sugarcane *riegos* is about 20% higher than the *riego* for other crops. This was legitimised by arguing that sugarcane gets water also during the dry season (when other crops are not allowed to be grown) and because sugarcane is the most profitable crop.

Table 6.1: Build-up of average total ISF for rice, example from *Comisión de Regantes* Muy Finca (Source: own data and Annual Budget 1998)

Type of fee	Average charges/costs	Per irrigation season per ha with average use of 8,000 m^3 per ha of rice (in US$)
Tarifa de agua	Volumetric: US$ 2 per 576 m^3	28.00
Cuota	Flat fee per ha: US$ 10/ha	10.00
	Volumetric: US$ 0.15 per 576 m^3	2.00
Maintenance in the tertiary block	3 days of labour, US$ 3.00 per day	9.00
TOTAL ISF		**49.00**

Also the board of the *Junta de Usuarios* and the ETECOM S.A. draw up their budgets in October. As their expected income depends on the fees set by the *Comisión de Regantes* and they know the water users will not increase the fees (beyond inflation), they will normally just copy the budget of the former year.

After the General Assemblies of the thirteen *Comisiones de Regantes* have decided on their budgets and have proposed the price of a *riego*, the board of the *Junta de Usuarios* (existing of the presidents of the *Comisiones de Regantes*) comes together to decide on the charge for the *riego*. The boards themselves see the need to increase the charge at least by ten percent to compensate for inflation, but if possible even more to be able to improve the performance of the irrigation system. However, the mandate they have from their General Assemblies is to maintain the present charge, or in some cases to increase by ten percent to compensate for inflation. The individual board members have to make a political decision: they might lose political support from the water users if they agreed on an increase of the fee beyond the proposal of the General Assembly of their *Comisión*. However, they also face budgetary deficits and decrease of service delivery level if they did not agree on an increase of the fee.

What has happened from 1995 to 1999 are two things: either the *Junta de Usuarios* decided to increase the fee for the *riego* by ten percent, or the *Junta* decided to maintain the price. In 1998 the *Junta de Usuarios* informally asked the ATDR to resolve the problem for them. The *Junta de Usuarios* on December 22, 1998 decided to maintain the price of the *riego* for 1999 at 6 soles, but asked the ATDR to come up with an ATDR-resolution overruling this decision and increasing the price of a *riego* to 7 soles. This was good for the board of the *Comisiones de Regantes* as this increased the income badly needed to cover the costs of O&M, but at the same time the *Comisiones* could blame the ATDR for increasing the price and so maintain the political support from the water users.

Table 6.2: *Tarifa de agua* component of the ISF per *riego* (= 1 hour with flow of 160 l/s at field intake = 576 m^3) in Chancay-Lambayeque (Source: Larrea and Ugaz 1999)

	1995	**1996**	**1997**	**1998**	**1999**
ISF per *riego* (in Soles)	4.00	4.80	5.50	6.00	7.00
Exchange rate Soles/US$	2.25	2.45	2.66	2.93	3.34
ISF per *riego* (in US$)	1,78	1.96	2.07	2.05	2.10

In Table 6.2 the *tarifa de agua* component of the ISF of the last five years is presented. The charge for one *riego* kept up with the inflation and was quite stable around US$ 2.00. Only after the *Junta de Usuarios* and the ATDR had approved the new ISF, the *Comisiones de*

Regantes could draw up the final version of the budget for the coming year. The boards of the *Comisiones de Regantes* did not consult the General Assembly of the water users again to make modifications to the decisions on the budget according to the final price of the *riego*.

However, the changes were normally small because none of the General Assemblies would have approved much increase in the price of the *riego* and thus the proposed price would be close to the final price. As remarked above, the price of the *riego* is far below the value it should have according to the Water Law. The Water Law set a minimum price of US$ 5 per *riego* for 1998 in Chancay-Lambayeque.

As the estimated volume of water to be sold was calculated on basis of the approved PCR and the official *módulos* for the corresponding crop, they made a number of mistakes. The total amount of water assigned to Chancay-Lambayeque (1,331 million cubic metres) was much bigger than the 75 percent chance of exceedance of the Chancay river (689 million m^3). In practice they could irrigate the planned area with this little water because the official *módulo* for rice (14,000 m^3/ha) was much higher than the actual amount of water requested on average in rice (8,000 m^3/ha). However, because of the less water sold in practice, the actual income from water selling (US$ 2.0 million) was also much less than calculated from the official water planning (US$ 3.7 million). This caused a problem for the *Comisión de Regantes* and *Junta de Usuarios*: they did not have sufficient financial means to execute the planned operation and maintenance.

Another error is that even if the planned volume of water would be correctly calculated, it would never be more than a prognosis based on past river flows. This prognosis is not a real forecast based on climate conditions to be expected, but rather a statistical tool to help estimate the possibilities of certain river discharges (de Bruijn 1999). River discharges might be much lower or much higher than the average, and this would affect very much the income for the *Junta* and *Comisiones*. Of course, especially low river flows would be problematic, as they imply less income and thus higher budgetary deficits.

The actually volume of water sold was almost always less than planned. The solution of the *Comisiones de Regantes*, *Junta de Usuarios* and ETECOM was to spend less money than was planned. This was a severe problem in Chancay-Lambayeque. Only during the irrigation season the total volume of water that would be sold became clear. Therewith also the total amount of money that would be raised became known. With this knowledge the boards had to put priorities in the expenditures. The *Junta* and *Comisiones* would first cut in the expenses for maintenance because the expenses for operation (wages for personnel) had priority. As maintenance forms only about 10 percent of the budget of the *Comisiones* this meant a constant neglect of maintenance in the secondary blocks. ETECOM budgeted seventy percent for maintenance and thus could - also if income was less - still do quite some maintenance of the main infrastructure.

6.2.3 Water price setting in Jequetepeque

In Jequetepeque the financial construction was similar to Chancay-Lambayeque except for two major differences. First, the *Comisión de Regantes* each had a decentralised budget for the O&M in their Subsector. This meant that the General Assembly of water users in the *Comisión* could opt for paying more *tarifa de agua* to increase the budget of their *Comisión* (with the consequence that they also paid more to the *Junta de Usuarios* and taxes). Second, the fee was a flat fee per hectare depending on the type of crop approved to be cultivated. Thus, they did not pay per actually requested volume as in Chancay-Lambayeque, but they paid a fixed price based on the volume of water officially assigned. The users paid the fee in parts spread over the irrigation season. For example for paddy: 30 percent before the first irrigation turn, 40 percent before the transplanting and 30 percent after the harvest. Fees ranged from US$ 48 to US$ 63 per hectare of rice per season, and US$ 22 to US$ 33 for a hectare of maize (see Table 6.3). The fee for sugarcane was around US$ 70. Also in Jequetepeque the users paid an extra flat fee (*cuota*) per user per hectare to the *Comisión de Regantes*. The *cuota* could be somewhere between US$ 1 to US$ 10 per hectare (e.g. Chepén US$ 2/ha).

Table 6.3: Differences in ISF in Jequetepeque in 1998-1999
(Source: own data)

Comisión de Regantes **de Regantes**	**Paddy (per ha/season) (US$)**	**Maize (per ha/season) (US$)**
Pay Pay	63	33
Jequetepeque	63	33
Tecapa	59	30
Chepén	57	30
San Pedro	56	29
Talambo	50	26
Limoncarro	48	22

During General Assembly meetings in the *Comisiones de Regantes* in October the water users debated heavily with the members of the board of the *Comisiones* on the proposed annual budgets. An example was the meeting of the General Assembly of Chepén presented in Box 6.1.

Meetings of the General Assembly did not always occur with that many confrontations, but especially in the bigger *Comisiones* it was a rather normal happening. Often it was the same 'opposition' group that attacked the sitting board. They tried to mobilise the unrest of the other farmers to win their votes in a next election.

As the amounts paid in Jequetepeque were not related to the volume of water delivered there was no problem in dry years: the same amounts had to be paid in dry or wet years. As in Chancay-Lambayeque the water users also had to provide labour for maintenance of the tertiary canals. This would be on average three labour days per hectare of irrigated land twice a year.

From turnover in 1992 to 1994 the ISF had been rather low. The water users were not willing to increase the fees paid before the turnover. With the new board of the *Comisión de Regantes* and *Junta de Usuarios* in 1994 this changed. The board managed to convince the water users of the need to increase the ISF so as to be able to finance the O&M. From 1994 to 1996 the ISF increased 300 percent. After 1996 the water users did not agree to increase the ISF any further and the value in dollars decreased due to inflation. Many of the 30 water users interviewed in Jequetepeque stressed repeatedly that they considered the ISF too high considering their low earnings due to the low rice prices and general economic crisis in Peru. As in Chancay-Lambayeque the actual *tarifa de agua* is much lower than the official fee established in the water law.

Box 6.1: Negotiations on setting of the ISF in CR Chepén (October 30, 1999)

In the brand new office building of the *Comisión de Regantes* of Chepén about sixty water users gathered (of which three women), out of the 730 officially registered water users. All were seated and had received a copy of the proposed budget. In front of the water users the *presidente* of the *Comisión*, the *jefe de sector*, the bookkeeper and the delegate* of the *Comisión* to the *Junta de Usuarios* were seated behind a table. The meeting started with the reading of the proposed budget by the bookkeeper of the *Comisión*.

Some of the users had objections. They asked how much the salaries of the personnel of the *Comisión* were. Some farmers considered them too high, especially the Christmas bonuses, which were some US$ 130 per person. The bookkeeper explained that these bonuses were the minimal legal bonuses for private companies and they were indeed higher than the bonuses in the public sector (US$ 65). A question that was asked repeatedly was whether or not the expenditures of the past year coincided with the budget set for that year. This seemed to be a rational question to ask, because in that way the water users (and board) could know if the budget could be passed this year without changes or whether the budget should be adapted according to the real spending of last year. However, none of the users had the balance at hand and the board refused to give a copy of the balance, arguing that all water users had received the balance before the meeting last summer when the balance was presented, discussed and approved. Apparently the board had something to hide.

The proposed annual budget was the same as the one presented and approved for the past five years. Therefore, the *jefe de sector* did not understand the commotion among the water users about this proposal:

"*You approved it the five last years, so why not approve it now, especially considering that the real costs for the Comisión have gone up. In fact we need more money to cover the recurrent expenses for O&M! I therefore propose an increase of the cuota from 2 to 3 US$, this is better for us than increase the tarifa because we only receive 25 percent*** *of the tarifa, the rest goes to the Junta*."

The water users did not approve the increase of the *cuota*. They proposed that the personnel of the *Comisión* used less fuel. However, after this being agreed, another group of water users came with a complaint about the fact that the '*despalizador*' (somebody clearing the siphon under the town of Chepén from debris to prevent overtopping and therewith flooding a part of the town) was only attending one particular siphon. According to them there were many more points where the canal needed daily cleaning of debris. The *presidente* of the *Comisión* silenced these complaints by explaining that there was no money (and the water users had just decided that the ISF would not be raised...).

The next point of objection of some water users was that they had the feeling that the big landowners had not paid their ISF. The *Jefe de Sector* explained that it was not true that the bigger landowners had not paid their fees. However, it was the sugarcane growers –big and small- who did not pay their fees. On the one hand this was because they always pay only at the end of the irrigation season, and for the last couple of years the sugarcane companies had been in deep economic crisis and had not paid to the farmers. On the other hand this was because some of the farmers had switched over to growing rice, and thus had to pay less (they used less water), but had not yet arranged the change in the administration, so they appeared to have debts with the *Comisión*. The water users were not satisfied with this answer and asked the bookkeeper to read out loud in the meeting all the names of water users with the amount of money that they owed to the *Comisión*. The list was being read and the farmers reacted on hearing certain names and the amounts they owed. The amounts varied between US$ 30 and US$ 1000, with a lot of farmers owing around US$ 150. The farmers were a bit reassured, because the large rice farmers appeared to have paid their fees.

* She is only female member of the board of Chepén and actively involved in local politics. She studied anthropology and became active in public functions after her husband died

** In Jequetepeque the *Comisiones* keep 25%, and in Chancay-Lambayeque 34% of the raised water tariff.

6.3 Fee recovery

6.3.1 Fee recovery in Chancay-Lambayeque

The fee recovery of the volumetric fee depended on the amount of water sold and the price set per volume. The volume sold depended on the amount of water available to be distributed and the percentage of losses and allocation of non-paid hours. The losses by seepage from the main, secondary and tertiary canals were officially calculated as being in total 25 percent. In this percentage the re-use of water was included. The amount of non-paid hours scheduled to fill up canals and 'head up' water was about 15 percent. It can now be calculated that with an average river discharge of 900 million cubic metres per year the maximum total fee to be recovered amounts to US$ 2.1 million. Actual fee recovery (average in period 1995-1998) was about US$ 2.0 million per year.

In Figure 6.1 the fluctuation of the value of the distributed water can be seen. This fluctuation was caused by the fluctuations in the availability of water in the river and the reservoir. In dry years like 1992 and 1997 the *Junta* and *Comisiones* had a problem in raising sufficient money to cover the expenses. However, also in the very wet El Niño year 1998 the amount of water sold was low because the farmers did not need to irrigate due to the flood, also after the flood passed the infrastructure was damaged to an extent that many areas that later demanded water could not be served.

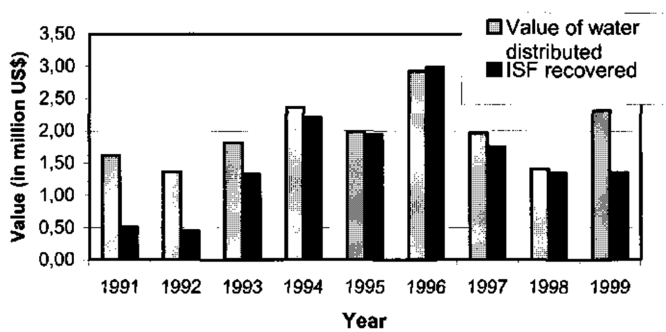


Figure 6.1: Value of water distributed and ISF recovery in Chancay-Lambayeque from 1991 to 1999 (Source: Larrea and Ugaz 1999)

However, what is important here, is the low fee recovery rate seen in Figure 6.1 for the years 1991 and 1992. Only less than one third of the value of the distributed water was recovered. From 1993 onwards the fee recovery was very close to the value of the distributed water, except for 1999. The low fee recovery rate in 1991 and 1992 was caused by the lack of 'discipline' of the *Comisión de Regantes*: they distributed water turns without prior payment by the water users. The water users were supposed to pay after the irrigation season, but most did not do so. Nevertheless they got water the next season. In 1993 the *Comisión de Regantes* and *Junta de Usuarios* introduced volumetric payment per water turn, and were very strict on the advance payment per water turn: 'no water turn without prior payment'. They also introduced the automated administration (SARA) of the water payments.

In the comparison between the value of the distributed water and the fees being paid one other aspect of the volumetric payment needs attention here. The value of the water was calculated from the total volume of water distributed taking into account an average of 25 percent conveyance losses. Thus, of each 720 m^3 taken in from the river 576 m^3 should reach a field and should be paid the price of one *riego*. Further, some 15 percent of the water is used to fill up the canals or head-up the water to be able to reach certain parcels. Thus, by knowing the intake from the river, one can subtract 25 percent conveyance losses and 15 percent distribution losses to know how much *riegos* should have been paid for if a 100 percent water fee collection rate was reached. Nevertheless, two factors make that the actual fee recovery can be even higher than the value thus calculated. First, the canal losses are not exactly 25 percent. If the losses are less, more *riegos* can be distributed from the same volume of water taken from the river. Another way of selling more *riegos* (to get more income for the *Junta* and *Comisiones*) is to deliver *riegos* that are less than 576 m^3 at field level. As water users cannot exactly measure the volumes delivered to them, it is possible and lucrative for the *Comisiones* to deliver less water and let the water users pay the full price (see Chapter 5). These factors can probably explain the high fee recovery in the years 1994 to 1998, and especially in 1996 when the fees recovered were more than the value of the water distributed.

The main cause for the low fee recovery in 1999 was that the sugarcane co-operatives did not pay their fees. The *Junta de Usuarios* had no control over the water abstraction by the head-end co-operatives and the co-operatives had a strong political support from the government. The sugarcane co-operatives defended their non-payment by referring to the traditional right of '*toma libre*' (this goes back to the Moche times: see Chapter 2) and the backup of the central government towards the co-operatives[4]. The *Junta* defended the distribution of water to the sugarcane co-operatives without prior payment by stating that it was better to give them water and possibly be able to recover some money from the co-operatives in the future than to let the water flow into the ocean and be sure no money could be made out of that in the future. However, this policy was almost never applied to the individual right holders, as this would severely undermine the prior-payment system, which made the fee collection so effective.

Another cause for the difference between the value of the water distributed and the fees collected was the allocating of free hours. When the *sectoristas* would give out too many free hours the fee collection would stay behind the planned fee recovery. As explained in Chapters 4 and 5, the *sectorista* could distribute hours of irrigation for free if he administered them under 'hours to fill-up canals', 'hours to head-up water', or 'hours to compensate for hours not delivered'. Giving out free hours, but letting the farmers pay to him directly, was very lucrative for the *sectorista*. It was also explained that the *Comisión de Regantes* monitored the percentages of free hours scheduled to control this form of corruption. An increase of monitoring and field measurements of hours needed in reality could result in an increase of 5 percent of the ISF recovery. The so-called '*riegos volantes*' did not influence the total fees recovered. Although the *sectorista* makes money by stealing water from official turns and sale of that water unofficially to another users, the official fees collected were not decreased. This is caused by the extra turns the deprived water users have to buy to compensate for the water they paid for, but never received.

[4] This government backup took a strange form when in 1999 government issued a decree in which it was stated that the sugarcane co-operatives could not be obliged to pay the individual farmers who had provided the cooperatives with sugar cane but whom had not been paid for this since more than two years. This decree goes against all reason and social justice and brought many smallholders to bankruptcy.

Although the fee recovery had some problems the system of prior payment per water turn seemed to work well compared to other fee payment systems in other irrigation systems around the world. Also locally other organisations that needed to recover funds from farmers envied the success of the Chancay-Lambayeque system. The local Ministry of Agriculture asked the *Junta de Usuarios* to help recover the credits distributed to small farmers for their maize and bean production. As in many cases, the farmers paid back only a very small amount. The *Junta* could enforce payment by denying water, but the Ministry could not recover the credit by such a system. However, the *Junta* did not help the Ministry with the recovery of the maize and bean credits. Playing the bailiff for the Ministry would harm the image of the *Junta*.

Photo 6.1: Water users waiting to pay their '*riegos*' at the ETECOM office in the *Comisión de Regantes* Lambayeque

Then, the physical aspect of the fee recovery: the fee collection. The ETECOM S.A. executed the actual collection of the fees. They had a small office with a computer in the building of all *Comisiones* and had a person working there each morning to collect the fees. At the end of the day the money was collected by a person who brought the money directly to the bank by car. The water users queued before the small service window to pay and get a receipt from the computer after payment (Photo 6.1). In the SARA computer programme the payments were automatically linked to the scheduling of the water deliveries. Not all water users went themselves to request and pay a water turn. It could frequently be observed that one person paid for a number of turns for fellow farmers. The NGO IMAR Costa Norte tried hard to introduce a system where a *repartidor* would schedule the water turns and collect the corresponding fees at a meeting place in the tertiary block itself. The *repartidor* would then go the *Comisión* and hand over the schedule of irrigation turns and the collected fees. ETECOM opposed this idea because they thought it would enhance stealing of the fees. In fact what would happen is that the *sectoristas* would lose part of their control over the water scheduling and delivery. For ETECOM it was easier to control the *sectoristas* than the *repartidores*. This control was important because, as explained before, the *sectoristas* (and *repartidores*) could make illegal money by selling more water turns than officially scheduled.

6.3.2 Fee recovery in Jequetepeque

As explained in section 6.1.3. water users in Jequetepeque had to pay their water fees in parts throughout the irrigation season. For example for rice: 30 percent before the first irrigation turn, 40 percent before transplanting and the remaining after the harvest. The fee recovery during the irrigation season was a problem in Jequetepeque. Water would flow everywhere without much control.

However, it was not a problem to enforce the first payment (together with any debts remaining from the former year), because the first turns for the rice-seedbeds were scheduled in arranged turns. If you did not pay you would not get a turn. In most places no water could be obtained from other sources, thus payment could be enforced. The farmers could not postpone the making of their rice nursery until water would flow abundantly, because the low temperatures affecting yield start in May. This forces the farmers to start rice growing before the end of November. Thus, the climate, the properties of the rice crop and the strict control over the first irrigation turns formed an 'obligatory point of passage'.

After the transplanting the water delivery was in continuous flow to all fields and from field to field. This made it very hard to exclude a water user who did not pay the next part of the ISF. Fee collection after the harvest was even harder because of lack of pressure from withholding irrigation water. Thus the *Junta* collected the fees at the beginning of the next irrigation season when strict control over water turns could enforce payment.

The control mechanism for excluding free-riders during the arranged scheduling of the first irrigation turns was not possible in all areas. In some places farmers used water from wells or drains to start the seedbeds and they did normally not pay the ISF. The *Junta de Usuarios* planned to force payment by coerced payment at time of harvest by picking up sacks of rice worth the debt with a lorry under supervision of a bailiff. This was regarded by the farmers as a very 'heavy' measure and made them angry.

The *Junta de Usuarios* sometimes artificially introduced water scarcity in a sector together with fee payment per delivered volume to get the water users to pay their ISF during the season. In fact they created a situation like in Chancay-Lambayeque where they had an arranged rotation schedule which made it possible to exclude non-payers from water.

In Figure 6.2 it can be seen that the fee recovery at the end of the irrigation season was quite good. The fluctuation of the value of the ISF to be recovered was caused by the different volumes of water available in the reservoir at the beginning of the irrigation season (more or less *campos* with rice) and the fee per hectare set for each crop. Contrary to the situation in Chancay-Lambayeque, in Jequetepeque the *Junta* could make a different PCR planning every year according to the water available in the reservoir. In Chancay-Lambayeque they made the same planning every year. Therefore, in Jequetepeque it was easier for the *Junta* to indeed collect the money being budgeted. Another difference with Chancay-Lambayeque that helped with the fee recovery was that the main *molino*, 'El Cholo' sometimes directly paid the ISF to the *Junta* as part of the credit deal with a rice-grower.

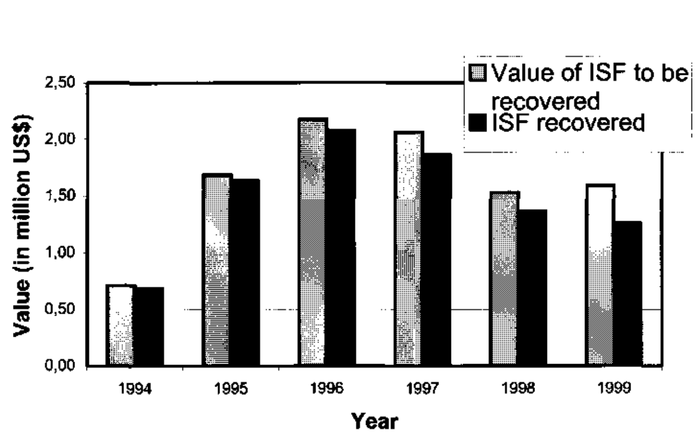


Figure 6.2: Value of ISF to be paid and ISF recovery in Jequetepeque from 1994 to 1999 (Source: *Junta de Usuarios* Jequetepeque)

The reservoir in Jequetepeque also posed a challenge in the ISF recovery in Jequetepeque. When the reservoir was at full capacity during the irrigation season, the farmers got very evasive in paying the ISF. They felt that as any spill from the dam would flow into the ocean anyway, they could take the water for free. It also became hard for the *Junta* to introduce artificial water scarcity in a sector to enforce distribution by turns and payment per volume while the dam spilled water into the river. This situation occurred for example in February 2000. The local television station broadcast shots of river water flowing into the ocean and wilting crops on land not being irrigated. This caused heavy pressure on the *Junta* to divert the water into the main canal, and not into the river flowing into the ocean.

Another problem with the fee recovery is that some farmers manage to make certain deals with the board of the *Comisión* on less ISF payment. The farmer then paid a sum to the board member lower than the official ISF and got water. This form of corruption was difficult to monitor from the administrative data the *Comisión* handed over to the *Junta de Usuarios*, because the illegal water users do not have a PCR, and thus were registered as not irrigating during that year. Only from comparing the areas that were really irrigated with the areas paid for this could be monitored. However, this takes a lot of field visits or could be done by remote sensing and/or satellite image interpretation (which was not done). The *Junta* minimised this form of corruption by only supplying the volumes of water to the *Comisiones* according to the area officially paid for. But, as farmers could in reality irrigate with less water than officially allocated the water not used by them could be allocated to illegal irrigators.

It is interesting to see that the total fee recovery, on average US$ 1.7 million, was almost equal to the amount raised on average in Chancay-Lambayeque (US$ 2.0 million), while the command area in Jequetepeque was less than half the size of the area irrigated in Chancay-Lambayeque. This has two reasons. First, the users in Jequetepeque paid more ISF per hectare than the users in Chancay-Lambayeque. Second, in Jequetepeque there were no sugarcane co-operatives that refused to pay like in Chancay-Lambayeque in 1999.

Two exceptions to the above findings on Jequetepeque are the *Comisión de Regantes* San José and San Pedro. In these CRs the ISF payment during the irrigation season was per volume, as practiced in Chancay-Lambayeque. As the budgets in Jequetepeque were agreed on decentralised, all *Comisión de Regantes* had the freedom to decide on their own budgets and ways of recovering the fees. The CRs San José and San Pedro decided to start the ISF recovery per hours of water sold some years ago because of the difficulties recovering the fees in parts. As in Chancay-Lambayeque, the users had to go to the office of the *Comisión* to request a water turn and had to pay in advance. However, an important difference with Chancay-Lambayeque was that at the end of the irrigation season the water users in San José and San Pedro had to pay at least the full 100 percent of the volume allocated officially to them. Only if they had requested more water than the official *módulo* did they pay this extra volume. Thus, the water users did not save money if they decided to request less water than officially assigned to them: at the end of the irrigation season they had to pay for the remaining volume, even if they did not request that volume.

The *Comisiones de Regantes* San José and San Pedro introduced volumetric water payment to make the collection of the fee during the season easier. However, when comparing the collection of the fees in San José and San Pedro to the collection of the fees in the other eleven *Comisiones de Regantes* during the 1998-1999 agricultural year, the *Comisiones de Regantes* of San Pedro, and especially, San José lagged behind in fee collection. This could be explained by the fact that in San José they distributed a lot of water without prior payment. What happened is that the size of the flows and the amount of free hours given were not controlled well. This had to do with the tradition of distributing 50 l/s, while this flow was 35 l/s on paper. Besides that, farmers did not accept the flow sizes when they were correct according to the volume they had paid for. They were used to much more abundant water flows to their fields and claimed much more water than they had paid for. After the soils were saturated the farmers could also easily get water flowing from other rice fields and from drains. This all helped to make the fee recovery rates in San José and San Pedro even lower than the fee recovery rates in the other *Comisiones de Regantes*.

The actual collection of the fees was very similar to the collection done in Chancay-Lambayeque. However it was personnel hired by the *Junta de Usuarios* directly who did the fee collection in the offices of the *Comisiones de Regantes*. The fees paid on one day could be a substantial amount, for example just before the transplanting of the rice, when up to 100 farmers could come to the *Comisión* on one day to pay on average US$ 100 (for five hectare of rice), being the part to pay before the transplanting. It was reported in December 1999 that two *Comisiones* had been assaulted by armed men who took the collected fees.

6.4 Expenditures

6.4.1 Breakdown of expenditure in Chancay-Lambayeque

In general much of the critique on the management of WUAs after IMT has been on the lack of expenditures for maintenance and lack of long-term investments (e.g. Oorthuizen and Kloezen 1995). Actual expenditures after the turnover of the *Comisiones* (1992) and main system (1994) in Chancay-Lambayeque are analysed at four levels: (1) the general distribution of the funds raised by the *tarifa de agua*, (2) the expenditures of the ETECOM S.A., (3) investment in capital assets by the *Junta de Usuarios*, and (4) the expenditures of the *Comisiones de Regantes*.

In Table 6.4 the allocation of funds raised from the selling of water is shown. The percentages of the payment to the government ATDR, AACH, and DEPOLTI were regulated by the Water Law. The one percent payment to the National Organisation of *Junta de Usuarios* was a voluntary contribution to the National Confederation of WUAs. The payment to ETECOM S.A. was also stipulated in the Water Law. The division between the *Junta de Usuarios* and the *Comisiones de Regantes* was decided upon by the *Junta*. Also the division between spending on operation and maintenance was the choice of the *Junta de Usuarios*, ETECOM and *Comisiones de Regantes* themselves. Of the total of the average actual expenditure of US$ 2 million per year, 34% was spent on operation, 52% on maintenance and special (rehabilitation) projects, 4% on fee collection and 10% on administration.

It is important to notice that the ATDR and DEPOLTI had means to enforce the payments of their share of the *tarifa* to them. Clearly it would not be sufficient that the Water Law stated that the *Junta de Usuarios* should give 4 % and 3 % of the collected fee to these agencies. The ATDR could enforce the payments because it was the ATDR that decided on whether or not new election should be held. So to stay in place the board of the *Junta* had to comply with the payment to the ATDR. DEPOLTI did the monitoring of the conduct of the ETECOM. The *Junta* did not want to lose the control over the management of main system. If DEPOLTI decided that the ETECOM was not managing well they could end the concession and take over the management of the main system themselves again. The AACH had less power to pressure the *Junta* directly, but was supported by the ATDR.

Table 6.4: Breakdown of the allocation of the *tarifa de agua* in Chancay-Lambayeque, averages 1996-99 (Source: Larrea and Ugaz 1999; tables 2 and 7)

Organisation	Activities		Expenditures (US$)	Percentage
Junta de Usuarios	Administration and special projects		375,000	19 %
ETECOM S.A.	Fee collection	(7%)	70,000	49 %
	Operation main system	(27%)	271,000	
	Maintenance main system	(66%)	640,000	
13 *Comisiones de Regantes**	Operation secondary canals	(90%)	340,000	19 %
	Maintenance secondary canals	(10%)	38,000	
AACH	Conflict management and special projects		100,000	5 %
DEPOLTI	Amortisation infrastructure Tinajones project, control of ETECOM S.A.		63,000	3 %
ATDR	Administration, monitoring and rule enforcement		83,000	4 %
National organisation of *Juntas de Usuarios*	Lobbying in Lima, exchange with other *Juntas de Usuarios*		20,000	1 %
TOTAL			**2,000,000**	**100 %**

* The expenditure of the *Comisiones de Regantes* only includes the *tarifa de agua* and does not include the money raised from *cuota*.

The private company of the *Junta de Usuarios* in Chancay-Lambayeque, ETECOM S.A. had the task to perform the operation and maintenance of the main irrigation system and maintain the drainage canals. In Table 6.5 the breakdown of the annual expenditure is shown. More than half of the funds went into the machinery and materials for repair. In total about eighty persons worked on a permanent basis for the ETECOM. On a temporary contract basis many more personnel could be working for special construction works.

Part of the funds of ETECOM S.A. and the *Junta de Usuarios* went into the investment in capital assets and an emergency fund. Table 6.6 enumerates the machinery bought by the

Junta to be used by the *Junta* itself, the ETECOM and the *Comisiones*. This indicates that from the total of US$ 5.4 million the *Junta* had to spend from 1993 to 1996 they invested 2.0 million US$ in capital assets and an emergency fund, which is more than 35 percent.

Table 6.5: Average annual expenditure by ETECOM S.A. (Sources: items: INRENA 1997, break up of expenditures are rough estimates)

Budget Item	Sub-item	Type	Numbers	Average annual expenditure (in US$)
Personnel	Operation	6 overseers and 27 tomeros	33	110,000
	Maintenance personnel	3 engineers, 5 financial administrators, 1 programmer, 1 mechanic, 17 tecnicos, 3 supportive staff	32	145,000
	Fee collection	One chief and 15 employees	16	70,000
Machinery		Heavy machines, lorries and pick-ups, fuel	33	356,000
Office and other materials and taxes		One head quarters, cement and personnel for repair of canals	-	300,000
TOTAL				**981,000**

Table 6.6: Investments of the *Junta de Usuarios* of Chancay-Lambayeque in capital assets from 1993 to 1996 (Source: Chinchay and Sijbrandij 1999)

Asset investments	US$
Front loader Fiat Allis FR-140	130,000
Excavator Komatsu PC 200	140,000
Pick-up truck with double cabin	69,000
Hydraulic excavator 325-L	288,000
Pick-up truck with simple cabin	32,000
Motorcycles	35,000
Tumbril of 12 m^3	190,000
Motor Komatsu 4D-130	39,000
Computers	40,000
Topographic instruments	5,000
Radio equipment	42,000
Subtotal	**1,010,000**
Emergency fund	1,000,000
Total	**2,010,000**

Table 6.7 shows a rough estimate of the breakdown of the total spending of all thirteen *Comisiones de Regantes*. It can be seen that for the *Comisiones de Regantes* the income from the *tarifa de agua* was not sufficient to operate and maintain the secondary canals. The income from *cuota* contributed a significant part of the income of the *Comisiones de Regantes*. The costs for the offices themselves and the personnel for operation clearly took the lion's share of the expenditures. The meagre amount reserved for maintenance and repair would be reduced further in dry years, when less income from the *tarifa de agua* came in. This was one of the main problems for the *Comisiones de Regantes*. Almost in all years the total amount of money raised with selling of *riegos* (US$ 2.0 million) was less than the budget calculated on basis of the PCR (US $ 3.7 million). Thus, in most years the *Comisiones* would execute less or none of the planned maintenance works. And also the *Junta* and ETECOM could do less than budgeted.

Table 6.7: Rough estimate of average spending per year of the 13 *Comisiones de Regantes* in Chancay-Lambayeque (Source: own calculations based on several annual budgets and annual balances)

Activity	Items	Costs per year	Expenditure (US$)
Operation secondary canals: personnel	14 *Jefes de operaciones* 25 *Sectoristas* 25 *Tomeros* 5 *Aforadores* 5 *Chofers*	14 * US$ 8,000 = 112,000 25 * US$ 4,500 = 112,500 25 * US$ 2,000 = 50,000 5 * US$ 2,000 = 10,000 5 * US$ 2,000 = 10,000	294,500
Operation secondary canals: material costs	Fuel, motorbikes, pick-ups		40,000
Office of the *Comisión de Regantes*	14 Bookkeepers 14 Secretaries 14 Guards Office building Telephone Office equipment Electricity and water Publicity 'Lunches' Public transport	14 * US$ 2,000 = 28,000 14 * US$ 2,000 = 28,000 14 * US$ 1,500 = 21,000 } 200,500	277,500
Maintenance and repair	Cement, iron, paint, construction workers		38,000
Total			**650,000**
		From '*tarifa de agua*'	380,000
		From '*cuota*'	270,000

Control over the spending of the *Comisiones* was exercised in three ways. The board of the *Comisión* presented a balance on the spending the past fiscal year. This balance was distributed to the water users and discussed and approved during a meeting of the General Assembly. It was hard for most of the water users to read and understand the balance. Nevertheless, the *Comisión* put effort in producing a 'sound' balance and in some occasions difficult questions were raised during General Assembly meetings by 'opposition factions' in the *Comisión*. However, normally little discussion happened in the General Assemblies on the balance in comparison with the presentation of the budget. It seemed the accountability of the board of the *Comisiones* is more in the sphere of services delivered and infrastructural works constructed than in the sphere of a financial accountability concerning the spendings of the board. The balances of the *Comisiones* were also checked by the *Junta de Usuarios* and the ATDR.

6.4.2 Breakdown of expenditure in Jequetepeque

The expenditures in Jequetepeque were of the same nature as in Chancay-Lambayeque. Two main differences are important. First the total amounts recovered with the sale of water in both systems was almost the same. As the command area of Jequetepeque was only half the size of the area of Chancay-Lambayeque, this means that in Jequetepeque there was twice as much money available per surface[5]. However, both Chancay-Lambayeque and Jequetepeque

[5] From comparing the budgets of Chancay-Lambayeque and Jequetepeque an administrative efficiency from large size can be seen. The thirteen *Comisiones* and the *Junta* in Jequetepeque spent almost the same amount of money as the thirteen *Comisiones* in Chancay-Lambayeque, which had more than twice the command area. Also within both systems it was clear that the larger *Comisiones* ran with less cost per area compared with the smaller *Comisiones*. However, it can of course also not be discarded that better maintenance increased the expenditure in Jequetepeque (although not many indications in that direction were found).

had the same number of *Comisiones de Regantes* with also more or less the same number of staff. This means that on average a staff member in Jequetepeque covered only half the area covered by a staff member in Chancay-Lambayeque. This together with the relative more scarce water in Chancay-Lambayeque made the job of *canalero* in Jequetepeque much easier than the job of *sectorista* in Chancay-Lambayeque. Only in items like fuel, *Comisiones* in Chancay-Lambayeque would have to spend more. This was covered by the higher *cuota*.

The second difference was that in Jequetepeque the *jefe de operaciones* was employed and paid directly by the *Junta de Usuarios* and not by the *Comisión de Regantes*. This made that in Jequetepeque the *Comisiones de Regantes* had one salary less to pay with the 25 percent they got from the selling of the water. It also had implications on the control over the work of the *jefe de operaciones*. In Chancay-Lambayeque the board of the *Comisión de Regantes* had the control and in Jequetepeque the *Junta de Usuarios*. As the *jefe de operaciones* did his daily work in (the office of) the *Comisión de Regantes* this could lead to conflicts. In one *Comisión de Regantes* in Jequetepeque there was an incident where the board of a *Comisión de Regantes* was not happy with the *jefe de operaciones*. They could not fire him. So what they did is not give him fuel for his motorbike so he could not go into the field.

As in Chancay-Lambayeque, also in Jequetepeque the *Comisiones* gave less priority to maintenance than the operation. This means that when fewer funds were raised little or no maintenance was executed in the secondary canals.

6.5 Subsidies

What has not become clear from the presentations of the expenditures of the water users' organisations, is the amount of subsidies received. The *Juntas* were proud of the high level of financial autonomy and tried to conceal the actual aid they received from government projects. The *Juntas* received subsidies in three ways. First, the Tinajones and Talambo-Zaña projects, which invested over US$ 308 and US$ 300 million (Thobani 1995), were not paid back by the users. The amortisation paid went to personnel of DEPOLTI to monitor ETECOM and OPEMA, land-tax went to the local municipality council and the tax on agricultural production was hardly paid by any farmer. Thus the Special Projects were never paid back by the users.

Second, the PSI project sponsored by the World Bank and Japan has financed the rehabilitation of the irrigation infrastructure after the El Niño floods of February 1998. The total amount of works in Chancay-Lambayeque and Jequetepeque is not known by the author, but must be more than US$ 4 million (source: www.psi.gob.pe). Also the Ministry of Agriculture and the Fondo Peru-Canada had some projects to rehabilitate infrastructure. Some of these rehabilitation works were executed by the *Juntas* itself and also IMAR Costa Norte rehabilitated three aqueducts. A third way of receiving subsidies was the training offered by IMAR Costa Norte and PSI. Both organisations have executed intensive training programmes for board members, personnel and farmers.

The change in the mode of financing caused by the IMT had implications for the control of the users over the operation, maintenance and rehabilitation of the irrigation systems. From 1970 to 1992 the government would pay the salaries of the personnel and therewith control the daily operation of the system. The water users were quite autonomous in how to organise the cleaning of the tertiary canals. For special works, rehabilitation or new constructions, the users who would benefit directly from those works would put together funds to finance the works. In that way the users had control over the design of these works. After 1992 the *Junta* and *Comisiones* took over the paying of the salaries of the personnel and thus gained control over the operation. They also took over control of the cleaning of the tertiary canals by appointing or approving the appointment of the *caporal*. However, the *Junta* and *Comisiones* had no money for rehabilitation works. Funds from the Ministry of Agriculture or PSI came in to execute these works. The *Junta* and *Comisiones* had no control over the design and execution of these works. Thus the domains of control were reversed.

Thus, although the initial investments were not paid back by the users, relative little subsidies were received or daily operation and maintenance. Exception were the rehabilitation projects after the El Niño floods. It must be mentioned also here that the *Junta* in Chancay-Lambayeque had insurance for the main canal Taymi. The insurance paid for the rehabilitation of the Taymi canal after the El Niño damage. In 2000 the government wanted the *Junta* to take over the payment of the insurance premium. However, the *Junta* did not accept this.

6.6 Conclusions

Two main differences were found between the financial conduct in Chancay-Lambayeque and Jequetepeque. First, in Chancay-Lambayeque a part of the total ISF to be paid by the water user is related to the volume of water requested by the water user. In Jequetepeque the ISF paid by a water user was a fixed charge per hectare per season differentiated per crop according to the officially allocated volume of water for that crop. Second, average prices per hectare were higher in Jequetepeque than in Chancay-Lambayeque. In Table 6.8 the ISFs are compared. Because the volumes of water used per hectare in Jequetepeque were higher the price per cubic metre was lower than in Chancay-Lambayeque, even though the price per hectare was higher. Water users spent about 5% of their total production costs on ISF[6] (see Appendix III).

Table 6.8: Total ISFs (including '*cuota*') per irrigation season in Chancay-Lambayeque and Jequetepeque (in US$) (Sources: Tables 3.5, 6.2 and 6.3)

	Chancay-Lambayeque		Jequetepeque	
	Dry year	Wet year	Dry year	Wet year
Total ISF for sugarcane				
- per season per ha	60	75	85	85
- per m^3	0.006	0.006	0.004	0.003
Total ISF for rice				
- per season per ha	46	53	65	65
- per m^3	0.007	0.006	0.006	0.003
Total ISF for maize				
- per season per ha	30	34	35	35
- per m^3	0.010	0.009	0.005	0.004

[6] However, the share of the costs for water is much higher if labour costs are not taken into account. The ISF is about 10% of the non-labour inputs for rice in Chancay-Lambayeque.

Volumetric payment was introduced in Chancay-Lambayeque after the IMT in 1992. The *Junta* and *Comisiones* saw it as a good means to recover the irrigation service fees. The advantage was that the fees were collected during the irrigation season (when the costs are made) and not after the irrigation season (when inflation might have decreased the real value of the charges). Also two *Comisiones* in Jequetepeque introduced payment of the fees per volume during the irrigation season to be able to collect (part of) the fees during the season. Increase of productivity of water and water conservation was not an issue for the *Junta* and *Comisiones*.

The volumetric payment per irrigation turn in Chancay-Lambayeque affected the accountability relations between the water users and the board (and staff) of the *Comisiones de Regantes*. The water users regarded the payment per volume as legitimate. The payment per volume was accepted as a 'market-like' transaction. However, this legitimacy was conditional: the water should be delivered according to the payment. Also the legitimacy was related to the influence the users could exert on the value of the fee and its expenditure. Because the General Assembly of water users could determine the fee and its planned expenditures to a large extent, the users accepted the fee payment per volume. The actual expenditures were not so transparent in reality, but the users seemed to accept that as long as the water delivery was perceived to be good.

As seen in Chapter 5, the water delivery at field level was on average very close to the schedule (and thus payment by the water users). When the farmer could convince the *sectorista* that not sufficiently water had entered the tertiary canal the *sectorista* would schedule a new water turn free of charge to compensate for the non-delivered water. About 2 to 8 percent of the scheduled turns were later compensated with free compensation turns. The big difficulty was that the inflows were not measured. Thus, neither the *sectorista*, nor the water users could prove whether or not sufficient water had entered the tertiary canal. Nevertheless, the institution of compensation for non-delivered water contributed to the accountability of the board (and staff) of the *Comisión de Regantes* towards the water users. Water users tried hard to get compensation when they had paid for, but not received, water. If necessary they would mobilise other water users, and try to put pressure on the *sectorista* and *presidente* of the *Comisión* to give the compensation. The *sectorista* would, however, not give compensation without a valid reason for the non-delivery. A valid reason could be a deficit in the delivery to the secondary canal or water stealing from the secondary canal upstream of the involved tertiary canal. In case of conflict about non-delivery the *presidente* of the *Comisión* would take a decision about compensation (sometimes after a field inspection and/or water flow measurement).

Each year the General Assemblies of the *Comisiones de Regantes* propose the charge for the irrigation service. The ATDR had to approve the charge. The level of the fee relates to the budgets for operation and maintenance decided upon by the General Assemblies. (Here they did no comply with the Water Law that established much higher minimum fees). In general, the water users want a fee as low as possible. The board (and staff) of the *Comisiones* and *Junta* want higher fees to operate and maintain the systems well. In the end the power balance between the stakeholders influences the degree to which their interests materialise in the agreed budget. The end results suggest that the *Comisiones* cannot convince the water users sufficiently to persuade them to pay a little more for the maintenance of the system. Especially the maintenance of the secondary canals was somewhat deficient in both systems.

The big question in the comparison is whether the ISF recovery in Chancay-Lambayeque was more effective (because volumetric) than the one in Jequetepeque. The comparison shows that in both systems the ISF recovery was quite high. The water users were forced to pay the fees because the *Comisiones* only delivered water after the fees were paid (in Jequetepeque the fees of last year were paid before the first irrigation turn). The recovery of the fees in Chancay-Lambayeque (and two *Comisiones* in Jequetepeque) was enabled by the scheduling and delivery of turns to individual water users during the irrigation season. In most *Comisiones* in Jequetepeque individual turns were only given for the first irrigation for rice (and in rare times of water scarcity). Sometimes water was 'made scarce' to enforce payments. In Jequetepeque the low temperatures affecting rice yield enabled the *Junta* to collect the fees at the beginning of the season (by forming an 'obligatory point of passage'). The *Comisiones* in Chancay-Lambayeque could only deliver water after payment of the fees, because they themselves only received water from the ETECOM after payment of the fees.

The main systems were maintained well by the private companies (to not lose the use-concessions) and also the tertiary canals were cleaned out very well every year. The subsidies for rehabilitation compensated a little the inadequate maintenance, but decreased the control of the *Junta* and *Comisiones* over the design of the works. The volumetric payment in Chancay-Lambayeque affected the *Junta* and *Comisiones* negatively because the volume of water sold depended on the river discharges that were very irregular, thus the incomes for the *Junta* and *Comisiones* also was irregular: low river flows meant little funds for maintenance.

One of the alleged difficulties of volumetric charging is that it is too expensive to collect water fees per volume from many smallholders. In Chancay-Lambayeque it was costly, for ETECOM, water users' associations as for the users themselves. The users had extra costs because they had to go to the office of the *Comisión* to pay for the water turns, and consequently had travel expenses and might miss one to several days of paid labour. They also might have had to pay interest over the money they borrow to pay the fees (while they were used to pay after the irrigation season with the money made by selling of part of the yield). The *Comisiones*, *Junta* and ETECOM had extra expenses because they had to measure, register and charge the volumes delivered to each individual plot. It is estimated that about ten percent more staff was needed to measure water flows, and administer and cash the fees per volume during the irrigation season. Thus, extra costs were not so high as sometimes suggested in literature.

7. Functioning and effects of volumetric water control

7.1 Introduction

In this chapter the findings of the previous chapters will be combined to come to a more integrated analysis of volumetric water control. First, the question will be answered to which extent the Chancay-Lambayeque and Jequetepeque irrigation systems can be regarded as volumetric systems.

Second, the governance and management to come to the volumetric water control, is studied. This is done by looking at the history of the infrastructure and institutions, and looking at the domains of authority of the involved organisations. Each domain has its proper institutions for rule making, rule enforcement and conflict resolution.

Third, the effects of volumetric water allocation, scheduling, distribution and charging are assessed. An evaluation is made of the effects of volumetric control on the productivity of water, the effect on livelihoods of different groups of water users, and the effect of the specific volumetric control measures on the overall governance and management of water.

7.2 Volumetric water control: fact or fiction?

In the foregoing chapters the history and present functioning of the volumetric water control in Chancay-Lambayeque and Jequetepeque has been described. The allocation to individual water users was expressed in volumes per hectare ('*módulos*'). Nevertheless, when water scarcity occurred in Chancay-Lambayeque the volumes that could be requested were reduced according to landholding ('*rangos*'). This is a 'share-based' measure in the sense that rules apply that make the allocation equitable (and not directed to crop water requirements). It was not market-competition that regulated water distribution in water scarce periods, but specific regulations that enforced an equitable distribution.

In Jequetepeque the allocation to individual water users was also expressed in *módulos*. However, also here 'share-based' practises could be seen. In the tertiary blocks the water was distributed in continuous flows without measuring the flow to each plot. In Jequetepeque in water scarce periods also fixed rules rather than market-competition regulated water allocation. When water scarcity was foreseen (empty reservoir) certain parts ('*campos*') of the command area were not allowed to grow rice.

In Chancay-Lambayeque the scheduling was on-request of the individual farmer. In water abundant years the water users could determine themselves how much water to buy. One hour of water cost about US$ 2 and should give 576 m^3 delivered at field level. Payment was in advance, one day before the delivery. This mode of scheduling implied a constantly changing program of water supply to the secondary and tertiary canals. In Jequetepeque in two *Comisiones* the same mode of water scheduling was applied. In the other *Comisiones*, in case of rice, the water was rotated only in the first weeks of the irrigation season. Here constant water flows were programmed each week to each secondary canal. The ISF was paid in parts during the irrigation season.

Water delivery in Chancay-Lambayeque was volumetric. Although few measurement structures were present, even in the tail-end tertiary block precise volumes were delivered according to the hours scheduled. In Jequetepeque the flows to the tertiary blocks were more than programmed, because water flowed back into the secondary canals from the saturated rice fields upstream of the canals. The weekly-programmed flows followed the theoretical crop water requirements according to cropped areas officially paid for.

Thus, to conclude, one can regard the allocation, charging and delivery in Chancay-Lambayeque as volumetric. Be it that in water scarce periods allocation and scheduling rules applied that can be called 'share-based', because they limit the volumes to be scheduled based on type of water right, crop and land size (regardless of actual demand). It was also different from the 'standard' volumetric control, because water was not measured at the field intake, no 'modern' irrigation infrastructure was used, and volumetric payment proved to have only very limited effect on water conservation by the water users. In Jequetepeque allocation and scheduling was also volumetric as it aimed at supplying water according to (theoretical) crop water requirements. However the charging of the Irrigation Service Fee (ISF) in Jequetepeque was not volumetric, as a fixed amount had to be paid (albeit differentiated per crop) regardless of the actual volume of water used. In two *Comisiones* in Jequetepeque a sort of hybrid form was used of ISF charging, as users paid per volume requested but had to pay up to the theoretical volume at the end of the irrigation season.

7.3 Understanding volumetric water control

The big question is why volumetric control could function like it did despite the many problems and constraints in infrastructure, river supply and institutional aspects. Material and social factors together shaped volumetric control. For example, social and material factors enable and constrain water delivery: water must be there, canals must be there, operators must have skills to operate, social control should prevent water theft, and low canals prevent water theft. However, it seemed that the 'traditional' irrigation infrastructure did not constrain the volumetric distribution much. Only the lack of flow measurement structures inhibited monitoring (by users and operators), and thus transparency, of the delivered flows. The open canal system required a lot of labour (in comparison with a closed conduct system) and resulted in less control over deficits and excesses in the tail-end.

How the institutions controlled the irrigation technology, the managers, the operators and users can be understood by looking at the continuities in the irrigation infrastructure and institutions, and analysing the involved organisations by looking at their domains of authority in decision-taking, rule enforcement (jurisdiction) and conflict resolution.

7.3.1 History captured in infrastructure and institutions

In Chapter 2 the history of the infrastructure and irrigation institutions was presented. From this description the paradox of the continuity has become clear. On the one hand some very abrupt changes have occurred in the organisation of irrigated agriculture in the North Coast of Peru, on the other hand a remarkable continuity (even from pre-Inca times) could be detected in the constructed infrastructure and daily routines of irrigation.

Sufficient abrupt changes can be pointed out: the brutal conquering by the Spaniards confiscating both land and water resources; the agrarian reform in 1969 turning over the land of the *haciendas* to co-operatives and the governance and management of the irrigation systems to the Ministry of Agriculture; and finally the turnover of the operation and management between 1989 and 1996 from the Ministry to *Comisiones de Regantes* and *Junta de Usuarios*.

Remarkably, the irrigation infrastructure and some important irrigation related practises remained almost unchanged during the last centuries. The basic ('tree-like') patterns in the layout of the canals changed little (except from some shrinking and expansions). Other characteristics of the infrastructure also survived for many centuries: the principle of heading-up water to divert it into offtakes (*'tomas altas'*), the relatively deep canals in relation to the surrounding fields, and the large flows (160 l/s) at field level in Chancay-Lambayeque. Also quite some present day activities might have been executed hundreds of years ago in the same fashion. For example the collective cleaning of the tertiary canals, the strict rotation starting at the head-end of the tertiary canal, and the principle that farmers profiting from a certain construction work contribute to the costs proportionally to their landholding. These practices were taken over by the *haciendas*, and after these the co-operatives and the Ministry of Agriculture, and after these the *Comisiones* and *Juntas*.

Also certain power relationships, partly sustained by location in the infrastructure and partly by institutions, remained intact. For example the sugarcane co-operatives can be seen as heirs of the Inca rulers. The informal right of the head-end water users to *'toma libre'* was institutionalised by the Incas and later used by the *haciendas*. The present sugarcane co-operatives still enjoy this *de facto* privilege. Likewise, different secondary and tertiary canals have different types of connection to the main system, reflecting the order of development of the command areas of these canals. In general a *toma alta* (and thus a more 'vulnerable' position in case of unprogrammed low flows) reflects more recent land reclamation.

It is hard to estimate how much the long history of the infrastructure and institutions contributed to the success in water management of the two irrigation systems. Surely the long tradition contributed to the legitimacy of the rules applied for allocation, scheduling, distribution and maintenance. Also the well-developed skills of the gate operators and irrigators can be related to the long tradition of irrigation. Despite the abrupt changes in organisation of the irrigation systems in most cases the same operators and irrigators could continue their job. For example in the case of the expropriation of the *haciendas*, the owners of the *haciendas* left, but the field personnel with years of experience remained, first as members of the co-operative and later as smallholders. Likewise, with the turnover of the system often the operators first employed by the Ministry were hired by the board of the *Comisiones*, private company or *Junta de Usuarios*.

Nevertheless, after both the land reform and the irrigation management transfer, new managers came in and new problems had to be tackled. New rules and routines had to be invented and new skills developed. An example is the collection of sufficient fees from many smallholders to cover the costs of operation and maintenance.

No final conclusion can be given, as no examples are available of irrigation systems that faced the same challenges as Chancay-Lambayeque and Jequetepeque, but lack their long history. However, the long history and continuation of certain practices is likely to have contributed to the high water delivery performance in Chancay-Lambayeque, the well organised maintenance of the tertiary canals and other management 'successes' in both systems.

7.3.2 Domains: rules, rule enforcement and conflict resolution

The control of the water users' organisations and the local governmental agencies over the irrigation water can be understood by looking at the domains of authority of these organisations. Within the domains the organisations have authority to make decisions, monitor and sanction rule violation, and resolve disputes and conflicts on specific matters. There exist all sorts of dependency relations between the organisations. The different interests, dependencies and external and internal rules shape power relations between the organisations.

Rule making and decision taking

Official rules regarding water allocation and use, and the tasks and obligations of the ATDR were formulated in the National Water Law of 1969. In 1989 the Ministry of Agriculture promulgated Decree 037-89-AG with detailed rules on the structure of authority of the ATDR and the different water users' organisations. The responsibilities, tasks, organisation of elections, and fines regarding the functioning of the board of both *Comisiones* and *Juntas* were formulated in quite some detail. The *Comisiones* and *Juntas* did not have any influence on this decree. Thus, the rules were exogenous to the *Juntas* and *Comisiones*. The Ministry had the objective to create organisations that could take over the management of the irrigation systems under surveillance of the ATDRs. The allocation of water (to individual titleholders) remained the exclusive domain of the ATDRs.

In practice the governance of the *Juntas* and *Comisiones* was surprisingly close to the rules established in the National Water Law and the Decree 037. The board of the *Junta* and *Comisiones* clearly used the official regulations to claim their domains of decision taking and jurisdiction. The laws gave them quite some autonomy to manage water distribution and financial affairs[1]. The boards thus created power in these domains with reference to the official rules. The three governmental decrees that cancelled the election of the boards increased the power of the boards even more.

Decree 037, however, stated almost nothing regarding rules on daily management for operation and maintenance. Also the statutes of the *Comisiones* mostly merely copied the rules on governance of the Decree 037 without any specification on activities of board and staff members concerning operation and maintenance. Hence, these rules were developed

[1] The *Juntas* and *Comisiones* did not adhere to some of the later decrees. The fees were set three times lower than the minimum fees prescribed in decree 003-90-AG, and the fines imposed by the ATDR were much lower than the minimum fine of US$10,000 established in decree 004-98-AG.

endogenously by the *Comisiones*, on the basis of former practices. Which people inside the *Comisiones* and *Juntas* could exert more influence on the formulation of these informal rules and which less, depended on power relations inside and outside the domain of the *Junta* and *Comisiones*. In general, the members of the boards of the *Comisiones* and *Juntas* could pretty much establish the informal rules for operation and maintenance themselves. Although the expectations of the water users were formed by the rights and obligations and service provision developed during the management by the Ministry of Agriculture (which in their turn were based on earlier practices).

In general, the rules on governance of the *Juntas* and *Comisiones* define clear boundaries to the tasks and obligation of the boards. The procedures for election of the board members, and the supervision by the ATDR, should in principle be able to guarantee a participation of the water users in decision taking, and accountability of the boards towards the water users and the Ministry of Agriculture. The authority to take decisions on water delivery, scheduling and maintenance, thus, was defined and practised according to State law. The rules on those daily management activities were developed and used by the boards themselves.

Rule enforcement

Personal interests of water users, board members and government officials make that rules get violated. Disputes and conflicts might arise over the appropriate application and interpretation of rules. Sometimes different interpretation of the same rules leads to such confrontations. In other cases people refer to different rules regarding the same issue.

Competition was an important force driving the strategies and activities of water users, board members, their staff and officials. Competition was important in the irrigation systems and roughly geared to two resources: water and political power. Both are strong forces. Agriculture is - albeit the low prices paid for the produce and high prices of inputs - still regarded as an important source to sustain livelihoods. Lack of alternative sources of income and love of the craft of being a good farmer make agriculture important. As the North Coast is a desert, water is a scarce and contested resource. The competition for water led to water theft. Also canal cleaning often suffered from free-riding.

Political power is also a desired resource. Being *presidente* of a *Comisión* not only gives access to illegal income, it also provides the position of a resource broker. Money and jobs can be distributed to 'friends' and being known as a good manager can help in a further political career (for example becoming mayor of a local town). Similar, being *presidente* of a *Junta* gives access to political power and resource brokerage. Money and power are gathered by bending and breaking of rules. For example, rules are violated to distribute water outside the official scheduling and use funds of the user' organisations for personal benefit.

Rules are monitored and applied (enforced) according to power relations. In the enforcement of the 'rule-of-law' three different situations can be distinguished. First, the 'normal' application in which routine monitoring is used to detect rule violation and punish offenders, regardless of the person, according to the established rules. Second, the situation where the enforcement of a rule is used in a political way by a powerful ruler to weaken the position of an 'opposition' leader or group. This is a selective use of a rule by the ruler for political purposes. In principle the rule can be 'just', but by using it selectively the rule-enforcement becomes a political instrument. A third situation of rule-of-law enforcement is when it is used for 'social empowerment'. In this case a socially less powerful person (or group) is protected by enforcement of a rule (e.g. a small tail-end water user actually gets the same volume of water per hectare as a big head-ender as established in a rule). This implies that the rule itself has the potential to empower less powerful people (e.g. laws on indigenous rights, equal access to jobs by men and women) and that powers are in place to enforce those rules (advocacy by an 'enlightened elite' or collective action by the less powerful).

All three mechanisms of rule enforcement were observed in Chancay-Lambayeque and Jequetepeque. As the organisations (*Comité de Canal, Comisión de Regantes, Junta de Usuarios*, ATDR, AACH, Special Project Bureaus) all have specific domains of authority for rule making, they also have specific domains for rule-enforcement. For example, the stealing of water inside the tertiary block is the domain of the water users in this tertiary block themselves and their *Comité de Canal*. Water theft inside the tertiary canal has to be detected and sanctioned by the water users. Normally the water user who has the water turn will guard her/his water against stealing and try to stop the stealing her/himself. In case this does not work the farmer will go to the *presidente* of the *Comité de Canal*. Social control among the water users is important and effective here. Higher authorities like the *Comisión de Regantes, Junta de Usuarios*, ATDR or AACH will not monitor nor sanction such theft. It is the exclusive domain of the water users and their *Comité de Canal*. This rule saves a lot of workload for the higher organisations.

Water theft by a water user (or group of water users) from a secondary canal, however, is monitored and sanctioned by the *Comisión de Regantes*. The *Comisión* itself might punish the water user by imposing a fine of paying ten bags of cement. However, the *Comisión* might also decide to do it the official way and report the water theft to the ATDR. The ATDR normally just imposes an official fine on the water user (on basis of the information of the *Comisión*). The water user may appeal against the decision of the ATDR with the AACH. The verdict of the ATDR thus can be reversed by the AACH after field inspection and taking testimonies of witnesses. Thus, jurisdiction on water theft from a secondary canal is shared with the *Comisión de Regantes*, the ATDR and AACH.

These examples illustrated that some infractions are only dealt with in one domain, while other type of infractions 'travel up' in the line of appeals. This depends on the type of rules involved. All organisations recognise different type of rules. The ATDR does not base its verdict on the internal rules of the *Comité de Canal*. It can only judge on cases for which the National Water Law provides legislation.

Table 7.1: Cases brought forward to the local offices of the ATDRs in Chancay-Lambayeque and Jequetepeque in the 1998-99 irrigation season (Sources: Archives of the ATDR of Chancay-Lambayeque and Jequetepeque)

Type of offence	Chancay-Lambayeque (22,250 users)	Jequetepeque (12,000 users)
Water stealing	36	9
Illegal paddy growing	0	7
Sowing paddy before start irrigation season	12	0
Alter canals and structures	14	1
Alter access roads	8	2
Alter drains	15	1
TOTAL	85	20

Table 7.1 gives the type and number of offences handled by the ATDRs in Chancay-Lambayeque and Jequetepeque. In Chancay-Lambayeque clearly more offences were handled than in Jequetepeque (also relative to the number of water users). Water stealing seems to be more a problem that cannot be resolved within the *Comités* or *Comisiones* in Chancay than in Jequetepeque. This can probably be related to the difference in water availability between both systems.

It is remarkable that in Jequetepeque seven fines were issued against farmers who grew rice without a PCR, against none issued in Chancay-Lambayeque for this offence. This is not related to the number of cases of illegal rice growing, as in Chancay hundreds of water users grow rice illegally. The difference has to do with the different ways of water allocation, charging and delivery in both systems. In Chancay the actual crop grown in the field does not matter so much and is not monitored by the authorities. Control is concentrated on the maximum water gift in water scarce periods. The volume allocated depends on the crop officially allowed to grow and other measures like '*rangos*'. If a farmer want to grow rice with the water allocation for maize that is her or his problem. In Jequetepeque there is continuous flow to all rice fields. Thus volumes allocated to individual plots cannot be controlled. Here it is important to monitor what crops are grown and sanction growing of crops with higher water requirements. By controlling the crop the total water demand is controlled.

In Chancay-Lambayeque twelve fines were given for starting to grow rice before the official start of the rice irrigation season. In Jequetepeque none. In both systems denying water at the start of the irrigation season is a way to make water users pay the ISF and fines and do the cleaning of the canals. As soon as a water user has started irrigating her/his crop (also if this is with water from her/his own well) it becomes very hard to deny this farmer irrigation water. Another, more practical, reason to fine early starting of rice growing is that the early start will disturb the growing season. The water user will need more water (as explained in section 3.3.1); and the water user will finish earlier than his neighbours and will then demand the others to stop irrigation to keep his rice field dry for the ripening of the rice. The early rice growing farmer is also regarded a free-rider, because he will profit from the still somewhat lower day-labourers' wages in rice transplanting and harvest, and the somewhat higher rice prices directly after the early harvest. The rules on planting date can be regarded as directed at co-ordination: they are not directed at exclusion, but at creating a fair and positive outcome for all water users. The exact dates are set by the *Comité de Coordinación*, and as the incentive to break the rules is high, the punishment cannot be dealt with within the group of water users themselves, it needs the authority and rule-enforcement of the ATDR.

In Jequetepeque early beginning of the rice growing was not punished by the ATDR. This is related with the different way in which the *Junta* tried to increase the ISF recovery. It seems that the *Comisiones* in Jequetepeque were pushed by the *Junta* to enforce the payments internally. In Chancay-Lambayeque the *Comisiones* use the authority of the ATDR to stop the early rice growing. Also with the altering of structures and canals there is a big difference in the number of cases handled: fourteen in Chancay-Lambayeque and only one in Jequetepeque. No clear explanation could be found for that, except that maybe more changes are made in Chancay because of the higher competition for water in that system. Also the difference in the number of cases for altering roads could not be explained (but realise that Chancay is four times bigger than Jequetepeque, considering this the number of cases is the same). In Chancay more cases on filling of drains were handled by the ATDR compared with Jequetepeque. This can be related to the severity of the salinity problems in Chancay.

The borders of canals, drains and access roads inside the tertiary block were regarded as 'common property' by the water users. Or better put: as belonging to nobody. For example people let their cows graze in the green borders along the canals and drains. A wide spread phenomenon was that water users bordering a canal, drain or access road each year expand their plot a little at the cost of the border of the canal, drain or road. In Chancay-Lambayeque sometimes minor drains were even filled to extend the plot, in Jequetepeque the minor drains were simply blocked and then planted with rice. As the borders of canals and drains grow smaller it becomes increasingly difficult to walk along the canals and drains for inspection. The narrow roads created problems for motorised traffic to the fields like: tractors and pickup trucks delivering fertiliser or transporting bags of rice.

The Water Law (Titulo VI, Art. 79, and its regulations approved in 1973: D.S. No. 929-73-AG) states that borders of rivers and canals belong to the State, and that there should be a surveillance road on either one or both sides of the river or canal. Along the main and secondary canal usually good maintenance roads are found. However, the tertiary canals seldom have a road running along the full length of the canal. Only if a specific group of water users is deprived of a certain service - like not being able to drain their fields or having great difficulties reaching their field by tractor - will they start to protest. Most probably they will first try to settle the problem among themselves, pushing the water user who expanded her or his plot to restore the borders. If this did not work, the group of deprived water users might look for help with the *Comité de Canal* and later the *Comisión de Regantes*. After filing of a complaint, the engineer or the *presidente* of the *Comisión* will visit the place and order the water users to restore the border to its original size. However, most borders are never restored and farmers have to live with the fact that their drain is filled or their access road too narrow. In some cases the water users and/or *Comisión* are persistent and file a case with the ATDR against the water user who enlarged her or his field. In total 23 complaints were filed with the ATDR in Chancay-Lambayeque and 3 cases with the ATDR in Jequetepeque concerning damage to (the border of) access roads and filling of drainage canals.

In Chapter 3 the domain of authority of the Autonomous Watershed Authority (AACH) was described. In dispute and conflict resolution the AACH plays an important role because it is the organisation that judges appeals concerning verdicts of the ATDR. In Chancay-Lambayeque in 1999 the AACH handled thirteen cases. From Table 7.2 it becomes clear that in most cases (11 out of 13) the AACH affirmed the decision of the ATDR. This makes it quite unattractive for a water user to appeal against any ruling of the ATDR. However, this depends much on the relations of the persons in the *Comisiones*, *Junta*, ATDR and AACH and the personality of the *Gerente Técnico* of the AACH. No complete data on the cases in Jequetepeque for the year 1999 were available, but according to some of the cases known and the data from 1995 the rulings of the AACH in Jequetepeque go very often against the decisions of the ATDR (5 against ATDR and 3 in favour of ATDR). Thus, in Jequetepeque it is more rewarding to appeal against the ruling of the ATDR with the AACH.

It is important to note that the ATDR and AACH depended on the *Comisiones* for the enforcement of the penalty by denying access to water to the offender until the fine had been paid. This makes that the ATDR and AACH could only effectively fine a water user if the *Comisión* agreed with the fine and saw need to enforce its payment.

Table 7.2: Cases handled by the AACH in Chancay-Lambayeque in 1999 (source: records from the AACH)

No.	Case	Ruling
1	Altering of canal by two brothers	AACH declares appeal to decision of ATDR ungrounded
2	Starting of cultivation of rice before start of rice irrigation season by six water users	AACH declares appeal to decision of ATDR ungrounded
3	Destroying border of canal and access road by water user	AACH declares appeal to decision of ATDR ungrounded
4	Water stealing from secondary canal	AACH declares appeal to decision of ATDR ungrounded
5	Altering canal	AACH declares appeal to decision of ATDR ungrounded
6	Renewed inspection	AACH declares appeal to decision of ATDR ungrounded
7	Flooding of neighbouring plot	AACH declares appeal to decision of ATDR ungrounded
8	Inheritance: splitting up of plot was not officially registered with the PETT, but ATDR recognised the split up.	AACH declares that document of ATDR is not legal because one of the documents used was not signed: AACH declares appeal grounded
9	Early growing of rice (same case no. 2: new ground for appeal is the economic crisis which made them start early)	AACH declares appeal to decision of ATDR ungrounded
10	Water stealing (see case no. 4: new ground for appeal: they took over the 1turn and did not know it was an illegal turn)	AACH declares appeal to decision of ATDR ungrounded
11	Member of board of CR has given water for growing sugarcane without PCR. Both farmers and board member appeal against their fines	AACH declares appeal to decision of ATDR ungrounded
12	Water stealing (see case no. 4 and 10; also this farmer claims he did no know it was illegal turn)	AACH declares appeal to decision of ATDR ungrounded
13	Altering canal (see case no. 1: with new facts appeal against decision of AACH)	AACH declares appeal to decision of ATDR, and AACH (case no. 1) grounded

If a water user or group of water users would file a complaint against a member of the board of a *Comisión* or *Junta*, the ATDR could only put pressure on the *Comisión* and *Junta* by threatening to have new elections for the board of the *Comisión*. But a substitution of the board is a 'heavy' measure and happened only seldom. However, also a member of the board could be charged and convicted of rule violation by the ATDR. For example, the ATDR and AACH imposed a fine for illegal sugarcane growing in CR Lambayeque (Case no. 11 in Table 7.2) on a former member of the board of the *Comisión* of CR Lambayeque. Nevertheless, these cases are rare, and payment of the imposed fine can only be enforced in the sitting members of the board agree with the penalty of a (former) member of the board.

Therefore, the ATDR and AACH cannot be seen as organisations that increase the accountability of the *Comisiones*. Only in extreme cases will the ATDR interfere in the management of the *Comisiones* or *Junta*. The active backup by the ATDR (and AACH) helped to maintain the status quo of the power held by the boards of the *Comisiones* and *Juntas*. The members of the board used the official rules and authority of the ATDR to reinforce their powerful positions.

Still, the accountability of the *Comisiones* towards the water users was high. Problems concerning non-compliance of water deliveries at field level were dealt with internally (as seen in Chapter 5). The *Comisión* were held accountable for deliveries according to schedule by the water users. The members of the boards would make efforts to comply with the schedule to satisfy the water users to win votes for the next elections. This proved to work well as hours of compensation were given in most cases of low deliveries. This accountability was quite remarkable if compared with the low level of accountability, and in some cases almost complete lawlessness, of the activities of the *molinos* (see section 2.4.3.). Besides the elections, the collective action of the water users (sometimes organised by IMAR Costa Norte) to protest against corruption, non-transparent management, and poor service delivery helped to enforce the accountability of the boards towards the users.

Dispute and conflict resolution

It is important to distinguish between punishment of rule violation (discussed above) and dispute and conflict[2] management (as discussed in this section), see also section 1.5.4. In both cases rules and conflicting interests are at stake. However, punishment of rule violation involves a party that claims that another party has violated a rule and also involves an authority that can impose a fine on the alleged rule breaker. In case of disputes and conflicts parties argue about the taking of a decision, or parties argue about an alleged rule-violation, but none of the parties has the power to enforce the decision or impose a fine (or come to a prosecution).

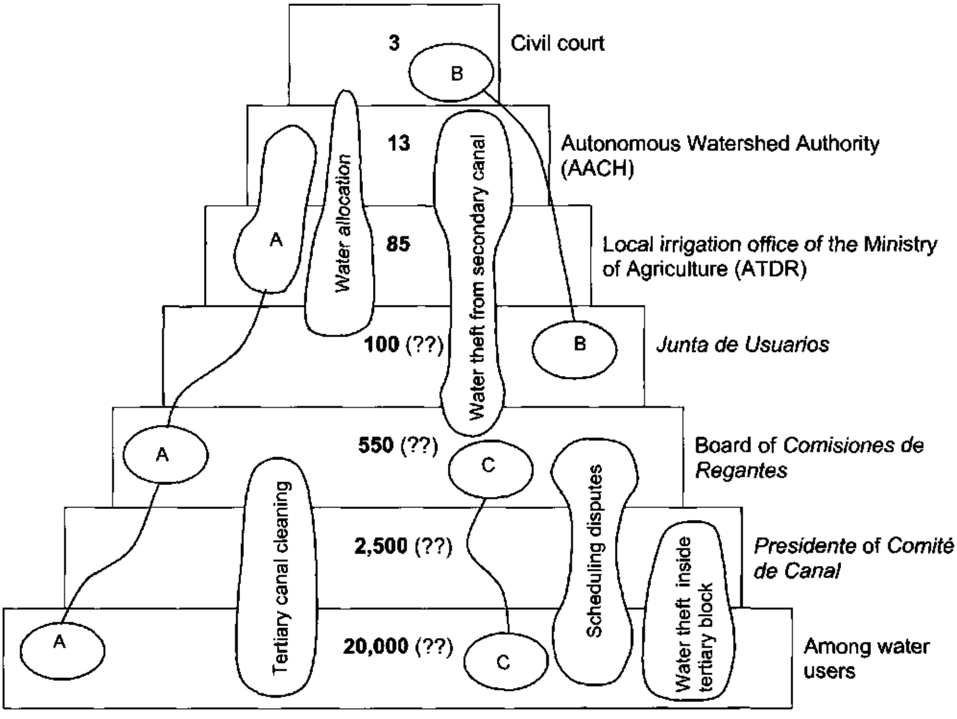
Both types of disputes and conflicts occurred. At different levels people argued about what rules to apply for taking decisions or question the application of the rule itself. For example the scheduling in the tertiary block (see Box 4.2), or the inclusion of illegal pumpers from the Taymi canal. Also the fight between the *Junta de Usuarios* in Jequetepeque and CEPRI-Tierras about the selling of the Pampa de Cerro Colorado was a conflict in which the stakeholders referred to different rules and different interpretations of the same rules (see section 4.2.2). In these cases the stakeholders each favoured different decisions based on different interpretations of rules or different sets of rules. Resolution of the disputes and conflicts was not easy. Sometimes a higher authority (the Civil court in case of the Taymi pumpers) 'resolved' the case by taking a decision. This management of conflicts, however, does not necessarily lead to acceptance and compliance. In other cases no authorities were in place to come to a decision, constructive negotiation or arbitration. For example, in case of the scheduling inside the tertiary block the power balance among the water users would lead to a certain scheduling of the turns. In the case of the selling of the Pampa de Cerro Colorado the *Junta* simply did not accept the selling and tried all means to find a legal bases to deny water to the new command area. For CEPRI-Tierras it is also not the solution of the conflict to just sell the land (as they are officially entitled to do so) because they need co-operation of the *Junta* to convey the water from the river to this new irrigated area.

Other types of disputes and conflict arise when one party accuses another party of breaking of a rule, but does not have the power to impose a fine or denounce the rule breaker. The conflict then involves putting pressure on the alleged rule breaker or a third party to try to influence the (future) strategy of the alleged rule breaker. An example was the conflict between the board of ETECOM and the *Junta* in Chancay-Lambayeque (section 3.4.8.).

Figure 7.1 illustrates some 'arenas of dispute and conflict management' in the 'pyramid' of organisations in the complex irrigation management entity. For example, it was explained

[2] Disputes involve a less 'hard' confrontation that still leaves open room for discussion and negotiation. In a conflict the parties are less willing to give in, and will continue the fight until they win or until they do not see any chance of winning anymore.

above that cases of water stealing inside the tertiary block are only dealt with among the water users themselves or involve the judgement of the *presidente* of the *Comité de Canal.* These cases are not allowed to 'travel' upwards in the line of appeals, because the *Comisiones de Regantes* and ATDR have the rule that water delivery inside the tertiary block is the responsibility of the involved water user and not of any higher authority. In contrast, water theft from a secondary canal is the competence of the ATDR. Consequently, appeals against fines can travel up the line of appeals (in theory up to civil court) in the 'pyramid' of organisations. Some of the other 'arenas' covering different levels in the 'pyramid' are depicted in the figure. In some cases some levels are 'skipped'. The figure clearly shows that although the organisations can be ranked in an order according to their level of authority (thus the shape of the pyramid) the arenas in which particular types of disputes and conflicts are handled only cover a limited number of the organisations.



A. Corrupt member in the board of a *Comision de Regantes*

B. Drinking water company EPSEL altered intake from canal in concession with a *Comision de Regantes* (EPSEL is one of the many organisation that fall outside the irrigation water management entity itself, but are involved in disputes and conflicts with this entity).

C. Disputes on setting of the Irrigation Service Fee (ISF) and accounting for the expenditures

Figure 7.1: 'Pyramid' of organisations indicating some arenas of dispute and conflict management. The numbers indicate the occurrence of dispute and conflict proceedings in 1999 in Chancay-Lambayeque. The number of cases with question marks are very rough indications

The figure gives also estimates of the number of cases handled in Chancay-Lambayeque at each level in 1999. The number of disputes and conflicts resolved among water users is hard to estimate. Also the cases processed at the level of the *presidentes* of the *Comités de Canal*, boards of the *Comisiones de Regantes* and *Junta de Usuarios* are hard to estimate[3]. The number of cases handled by the ATDR, AACH and civil court are known from the records these organisations keep. Not withstanding the rough estimation of the numbers, it becomes clear that the 'decentralisation' of dispute and conflict resolution is very functional for the organisation. It would imply much more costs if all the cases had to be dealt with at higher levels.

The disputes and conflicts reveal much about the interests of the stakeholders, the rules they use to claim their rights, and the power and authorities involved resolving the cases. The cases also show that certain issues are fought over in specific domains.

7.4 Effects of volumetric water control

7.4.1 Effects on productivity of water

In the comparison between two irrigation systems indicators can be used to make some 'hard' comparisons on the effect of Volumetric Water Control (VWC). In Chapter 5 on water distribution the DPR was used to assess the water delivery performance. Another indicator, which looks more at the overall outcome of the allocation, distribution, and cultivation practices, is the productivity of water. Productivity can be expressed in different ways depending on what evaluation criterion is considered to be important in a particular context. One is the net profit farmers make on average in an irrigation system with the use of 10,000 m^3 water (see Table 7.3).

Table 7.3: Rough calculations of productivity of water in Chancay-Lambayeque and Jequetepeque

Irrigation system		**Water use** (million m^3)	**Production**	**Productivity per 10,000 m^3 of water**
			Net profit for users (million US$)	Net profit for users (US$)
Chancay-Lambayeque	Dry year	568	12.7	220
	Wet year	1083	73.4	600
Jequetepeque	Dry year	383	9.6	250
	Wet year	827	17.6	210

It must be stressed that the calculations are based on very rough estimates. For example, the average yield of sugarcane was estimated from few field observations only (and some official data), but influence the outcome of the monetary comparison quite strongly. The productivity was calculated by dividing the total net benefit (cropping pattern as in Table 3.5 and net profits as in Appendix III with 'optimum' treatment for wet years and 'minimal' treatment for dry years, rice being an exception as the 'optimal' treatment is taken also in the dry year for

[3] The numbers given in the figure are based on observations in the field: two disputes per day during the 100 days of the irrigation season in the 100 *Comités de Canal* would result in 20,000 disputes per year in Chancay-Lambayeque. An estimated two disputes per week are dealt with by the 100 *presidentes* of the *Comités de Canal*. This results in 2,500 cases. The 13 *Comisiones* deal with three cases per week, and the *Junta* with one case per day.

Jequetepeque, and rice is taken to give only a 270 US$/ha profit in Chancay-Lambayeque in a wet year, and profit from beans is taken to be similar as profit from maize). The net profit for farmers is affected much by the market prices for labour, inputs, and the produce. Therefore, the productivity expressed in net profit per 10,000 m^3 of water is very relative. More absolute would be to compare productivity of water expressed in kilo Joule per 10,000 m^3 of water used. However, that would result in a bias favouring sugarcane as sugarcane contains much more kilo Joules than the other crops.

In the Chancay-Lambayeque irrigation system the productivity of water per unit of water was higher than in Jequetepeque. Although the average yields per hectare in Chancay-Lambayeque were lower than the yields of the same crops in Jequetepeque, the high water use in Jequetepeque made that productivity in Jequetepeque was lower.

What causes this reduced water use per hectare in Chancay-Lambayeque? The market (via paying of water turns) or regulation (via allocation quota)? Both. However, the allocation plays a much more important role than the market-incentive. Water users in Chancay would surely not buy *riegos* and let them flow into a drain. As farmers are conscious users of their costly water, they will not over-irrigate or apply water when not necessary. In Appendix V the effect of charging per volume is shown. About 10 to 20 percent more area could be irrigated with the same river supply after the introduction of volumetric payment in 1992. However, the re-allocative effect was bigger with lower river discharges than with larger river discharges. This indicates that other factors than the charging per volume contributed to the larger cultivated area. For example, the reduced growing of sugarcane, better reservoir management, and better monitoring of the maximum allowed volumes per hectare per season in water scarce periods, all seem to have contributed to the larger cultivated area after 1992.

In Jequetepeque water flows in and out of rice fields, and the rice fields are flooded permanently even just before the harvest, when it would be wise to let the land dry out. This over-user of water might have been stopped with volumetric payments (but was not due to the flat-fee paid).

Water users in Chancay-Lambayeque were, however, not forced to save water only because they had to pay per volume. In water scarce periods (and that was quite often) water allocation was rationed proportionally to the land holding with progressive diminishing ratios ('*rangos*'). The water in Chancay was scarcer than in Jequetepeque because the government in 1969 extended the command area by 40% (and the water by 24%) thus breaking the 'luxurious' water rights the *haciendas* had possessed. Hence, the difference in water supply in relation to the land irrigated makes that Chancay has higher water productivity.

The volumetric water payment in Chancay was not introduced to save water, but to increase the fee recovery. In fact, the volumetric payment was made easy by the 'imposed' water scarcity, because the scarcity already necessitated the rotation of water turns. Even before the introduction of volumetric payment the Chancay system used less water per hectare, just because relatively more right-holders had to share the scarce resource.

Interestingly, the illegal practices in Jequetepeque increase the productivity of the water somewhat. Illegal selling of water to farmers that did not pay the fees for their land resulted in wider spreading of the water and thus higher productivity of water. (This effect is estimated to be less than ten percent and was not taken into account in Table 7.3.)

Besides the direct effect of VWC on productivity of water some indirect effects occurred. For example, the increased responsiveness (on-request scheduling) and accountability (direct compensation for non-delivery) contributed to a good timing of the water deliveries at field level. This timeliness contributed to higher production and less field application losses.

To conclude we can say that the allocative efficiency was not increased by volumetric water charging. In Chancay the imposed water scarcity already made the water users rotate turns. The volumetric charging only increased the fee collection during the irrigation season. Technical efficiencies might have increased somewhat because of the better timing of the irrigation gift due to the on-request scheduling and high delivery performance.

7.4.2 Effects of VWC on livelihoods of water users

The effect of volumetric water control on different groups of water users is hard to assess. In the comparison between the production strategies and livelihoods of users in Chancay-Lambayeque and Jequetepeque more differences occur than those caused only by volumetric water control. In the first place the users in Jequetepeque have more water available per hectare than their colleagues in Chancay. In Jequetepeque the water users do not need to go to the *Comisión* to request water turns (except for the CRs San Jose and San Pedro). This saves per farmer at least 20 trips to the office of the *Comisión* per year.

The main effect of the volumetric water payment in Chancay-Lambayeque is that no water turn is given if the turn is not paid for. This means that poor farmers, who often have no cash and cannot easily get credit, might be skipped in the water rotation. It was observed in tertiary block La Ladrillera & La Colorada that in water abundant periods several rice fields were without a water layer while their neighbouring fields had water layers of at least 10 cm. Upon asking why their fields were dry they replied to have other priorities for their scarce funds. Resource poor farmers often had no cash and had difficulties to obtain credit (men asked their wives to sell a chicken to be able to pay another water turn). The relation between access to money and access to water was not investigated, but from the observed practices and interviews it became clear that the payment per water turn must affect the access to water, and thus increase the social differentiation among the farmers. However, the ISF in total contributes only 5% to the total production costs of the high-input production system. If a farmer cannot find funds to pay those 5% the farmer will in most cases not be able to buy other inputs and pay labour as well for the high-input production. With lower inputs the benefits decrease sharply (as seen in Appendix III). Thus, the volumetric payment itself cannot be blamed for the social differentiation, it is the more general condition of high-input agriculture with marginal benefits that caused social differentiation.

Moreover, the effect of volumetric payment is far less than the effect the (volumetric) water allocation itself has. Whether a farmer is allocated water for rice or for maize has much more effect on the farmer's income than the exact number of water turns the farmer can buy. An even bigger influence on the livelihood of a farmer has the amount of irrigated land (s)he has access to. Complete *comunidades* were excluded from water rights in the past, and the last couple of years *molinos* have been able to 'expropriate' land of small holders (see Chapter 2).

In the end, State regulations on water allocation and rules on sharing water in times of water scarcity had much more influence on livelihoods than selling of water by volume.

7.4.3 Effects of VWC on governance and daily management

Did the differences in modes of allocation, scheduling, charging and delivery between Chancay-Lambayeque and Jequetepeque cause any differences in more general governance and management between the two systems? Yes; in Chancay-Lambayeque there was more interaction between water users and the staff of the *Comisiones*. Also in Chancay-Lambayeque the payment per hour made the board and staff somewhat more accountable towards the water users. The scheduling and delivery of water in exact volumes induced the idea that you must receive what you paid for. In Jequetepeque, where water supply was less coupled to providing exact volumes the accountability worked differently. In Jequetepeque users had to arrange the continuous water supply to their fields among themselves. The *canalero* delivered a certain flow (in most cases amply sufficient to meet demands) to a *campo*. Pressure could be put on the *canalero* to give more water to the *campo*, but not to regulate flows to individual fields.

The charging (differently organised in both systems) had specific effects on the functioning of the systems. In both systems the cost recovery was high. In Chancay-Lambayeque a high fee recovery was achieved by the charging in advance of water turns and not providing water without prior payment officially. These official rules were enforced by only passing water to a secondary canal according to the volumes paid for. Thus, the water users and *sectoristas* were left no choice but to pay officially for each hour of water. Nevertheless, the operators managed to distribute some ten percent extra turns and could make quite some illegal money with that. This illegal selling of water, however, did not undermine the system of volumetric payment and even increased the precision of water delivery (to be able to extract the extra water) and thereby increased the performance of the water delivery. This was only possible because of the high skills of the operators. The illegal water turns could not 'expand' beyond the ten percent (and less in water scarce periods) because the water users paying for official turns were very keen on getting the water they had paid for. Also the staff and board of the *Comisión* were forced to supply according to schedule (coerced by the fear of non-continuation in next elections). The 'stealing of water' by the operators (and higher staff and board) did not necessarily lead to less (official) income for the *Comisión* and *Junta*, as the deprived users had to buy extra (official) water turns as they received for example only 145 instead of 160 l/s[4]. In Jequetepeque the mode of charging was not per water turn: here illegal money could be made by selling water to landholders that did not pay their water fee and thus were not entitled to any water. This illegal selling increased the productivity of the water used on system level. The effect, of course, was that members of the boards of the *Comisiones* and *Juntas* became rich. The posts in the boards and staff were highly desirable jobs.

[4] This can be compared with theft in a shop (where indeed sometimes the personnel steal more than thieves): the profit of the shop will not be less, it is the honest customers that in the end pay more for their products to compensate for the theft.

8. Conclusions and reflections

In this last chapter the answers to the research question and sub-questions are presented. This is followed by some reflections on the study. First, some reflections are presented on the used theoretical concepts and methodologies. Second, some brief thoughts are outlined on implications of the findings for interventions related to water control by development agencies in existing large-scale irrigation systems. Finally some ideas are presented for further research concerning the volumetric water control.

8.1 Conclusions

This study has shown the importance of understanding the different dimensions of volumetric water control and the institutions they involve. The irrigation infrastructure and the institutions involved in control of water and people evolved throughout the long history of the systems. Political processes shaped the rules for governance and management during different 'epochs' each with a different balance between local and national, and private and public control. Most generally we can conclude that the volumetric control in Chancay-Lambayeque functioned well in the sense that water was allocated, distributed and paid according to volumes. In water abundant situations the water users could request as much water as they wanted (as long as they paid for the volumes requested) and in water scarce periods water would be rationed and scheduled in fixed rotations with water allocations depending on the type of water rights, crop allowed to grow and land size. The water delivery at field level was on average according to the schedule. This high water delivery performance was not expected. The irregular river flows, the complicated (on-request) schedule; the open canals; the manually-operated, undershot gates; the lack of flow measurement structures at lower levels; and the poorly trained operators were expected to make it difficult to achieve accurate volumetric water delivery.

In Jequetepeque water supply was more abundant because the water was still concentrated on the lands of the former *haciendas*. Here water delivery was usually more than the programmed flows. In both systems water allocation was found to be unequal (some can grow rice, others not), but the water titles were based on historic patterns of land use, and not on political favouritism or social power of individual farmers. The volumetric fees were agreed by the General Assemblies of the users. These Assemblies prioritised the expenditures and tried to keep the costs as low as possible. The fee-recovery was high. Water users were forced to pay the fees by denying them water unless they paid. The water users could operate and maintain their systems, although maintenance on the secondary canals was sometimes deficient.

To answer the sub-questions here the main finding on the performance and organisation of volumetric water control are summarised (see also Table 1.2):

The complex entity that manages irrigation

Volumetric water control was executed by a complex entity consisting out of different organisations. This structure had developed from political processes including Irrigation Management Transfer. The water users' organisation consisted out of three tiers (tertiary, secondary and main system level). At main system level the *Juntas* formed private companies to execute the operation and maintenance. There were three local governmental organisations involved in the management of the systems. Each of the organisations had its own domain in which it had authority to take decisions on certain topics, sanction breaking of rules and resolve conflicts. The different interests of each organisation and spreading of decision-taking powers over the different organisations made that there was not one organisation that had the monopoly of control over water. The delicate power balance among the different organisations shaped relations of (mutual) accountability. Within the water users' organisation on the different levels of the system 'opposition' groups monitored the activities of the sitting board. Being a member of a board was a desirable post, because of the money made by illegal selling of water. However, corruption was limited by the control of the 'opposition' groups and other water users. The contradictory result was that on the one hand the board members wanted to be re-elected in next election to remain in the beneficial position, but on the other hand the board members could not be too corrupt or else they would not be re-elected.

Volumetric water allocation and scheduling

The local irrigation office of the Ministry of Agriculture (ATDR) decided on who were entitled to irrigation water. This was based on historic patterns of water use and political decisions. The ATDR also established the crop to be grown of individual titleholders and therewith the maximum volume of water to be used per hectare per irrigation season. The planning of the irrigation season was done together with the *Junta de Usuarios* and *Comisiones de Regantes* (in the *Comité de Coordinación*). This was essential for the legitimacy of the plan, as the *Comisiones* had to execute the plan. The *Comisiones* complied quite strictly with the cropping plan. It was also in their interest to avoid claims of farmers and be able to legitimise their actions by referring to the cropping plan. 'Perverse incentives' made individual board members and staff divert water to farmers without permission to irrigate (for personal benefit), but illegal water deliveries were limited by control by higher authorities, and opposition groups of water users.

The gross water demand was thus regulated that in Chancay-Lambayeque in most years total water demand would be more than the river supply. In Jequetepeque the luxurious water right position of the *haciendas* remained unchanged (until recently) and gross water demand would in most years be covered by river (and reservoir) supply.

Co-ordination and competition led to refinements of general rules on allocation and scheduling. At different levels competition for water resulted in disputes and conflicts over water rights and allocations. Claims in those conflicts were based on different normative and legal principles and often included technical arguments. In case of (unexpected) water scarcity a fine-tuned set of rules (e.g. '*rangos*' and '*campos*') were used to allocate the scarce water. Also the formal *licencia* and *permiso* water rights were adapted to local needs. In Chancay-Lambayeque the excess (*permiso*) right holders were actually excluded from water in water scarce periods, whereas in Jequetepeque the local rule on '*campos*' was more important than the formal *licencia/permiso* rule to regulate water allocation in water scarce periods. Matters of equity, water user efficiency and possibilities for control and monitoring played important roles in the regulations. Scheduling in Chancay-Lambayeque was on request of the water users. Only in times of water scarcity restricted numbers of hours would be scheduled according to size of landholding. In Jequetepeque in most cases water was supplied in continuous flows, without scheduling per turn. Individual water turns were scheduled only: for non-rice crops; the first irrigation turn for rice; in rare periods of water scarcity; and in order to increase fee recovery.

Volumetric water delivery

The irrigation infrastructure developed gradually from ancient time onwards. The *haciendas* replaced fixed offtakes by undershot sliding gates to gain more control over the water flows. After the land reform in 1969 those same canals and division structures stayed in use. However, after the parcellation of the co-operatives mid 1980's many smallholders had to be provided with water, complicating the water delivery. In Chancay-Lambayeque the relative water scarcity increased by the extension of the irrigated area, thus increasing even more tensions in the operating of the division structures.

Water distribution to the secondary canals was planned by the engineer of the private company and executed by *tomeros* along the main canals. At secondary level the *jefe de operaciones* of the *Comisiones* planned the delivery to the tertiary canals and this was executed by the *sectorista* and *tomeros*. Inside the tertiary blocks the users themselves were responsible for the distribution of the water.

The Delivery Performance Ratio (DPR) in Chancay-Lambayeque was quite close to unity, indicating that delivered volumes were close to the programmed volumes. This not withstanding the irregular river flows, difficult to operate underflow sliding gates, on-request scheduling by many smallholders, open and mostly unlined canals, and small number of measurement structures. High delivery performance was related to the low Relative Water Supply (RWS) of 0.6 to 0.8 at field level, indicating water scarcity.

The high delivery performance was possible because of four important factors. (a) Skills of the operators, who used 'manual feed back loop' to distribute the water by knowing only the measured inflow. (b) The coercion the users exercised on the operators to deliver the paid for volumes. They could force the operators to work well because with many complaints the board members would have to dismiss the operator to not lose their position in the board the next elections. (c) The interest the operators had in not delivering more water than programmed to save water to sell illegally. (d) Labour put in by the water users to supervise their water turns inside the tertiary blocks.

What remains difficult to understand is how delivery performance could be so good to many smallholders in a large-scale system without discharge measurement at tertiary intake and field level. In negotiations about the water delivery at field level between the *sectorista* and water user no reference could be made to any 'hard' measurement of the flow. Farmers used their own benchmarks (literally!) to know how the water supply was relatively to former deliveries. Also the *sectorista* had only relative indications on actual discharges. Only in very exceptional cases were discharge measurements executed with a propeller meter. Still, the disputes on water delivery were settled and water delivery was on average quite close to the programmed (and paid for) volumes.

Water users tried to steal water, but water theft inside the tertiary blocks accounted for less than five percent of the totally distributed water. Theft was mainly limited by the mutual social control and vigilance by the water user of the water flow from the tertiary intake to the field during the irrigation turn. Also the irrigation infrastructure limited water theft: padlocks on gates and 'low canals' limited the possibilities for water stealing.

In Jequetepeque mostly more water was distributed than planned. This because of extra water flowing into canals from saturated soils. Because of the abundance of water (RWS of 1.3 to 2.0 at field level) no strict control was exercised over the water flows. Nevertheless, also here the operators were skilled and water users exercised coercion towards the board of the *Comisiones* to get their share of the water flows.

Volumetric water charging

The operation and maintenance of the Chancay-Lambayeque and Jequetepeque irrigation systems was almost entirely financed by charging fees from the water users. Only subsidies came in for rehabilitation works. The water users also paid about ten percent taxes to the government, which financed partly the local irrigation office (ATDR), the watershed authority (AACH) and the Special Project Bureaus. The internal allocation of the funds among the *Junta*, private company, and *Comisiones* was decided by the *Junta de Usuarios*.

In Chancay-Lambayeque and Jequetepeque the fees were defined by the General Assemblies of the water users in the *Comisiones*, and had to be approved by the ATDR. The water users preferred low fees while the boards of the *Comisiones* and *Juntas* preferred somewhat higher fees to cover the expenses for operation and maintenance. The power balance resulted in fees that were in general almost sufficient for good operation and maintenance. The funds were allocated to the different sub-organisations in such a way that the *Comisiones* had insufficient fees to operate and maintain the secondary canals properly. As they preferred expenditure on operation above maintenance, the maintenance of the secondary canals was somewhat deficient. To get some extra funds the *Comisiones* established *cuota* to be paid partly as flat rates per hectare and partly as volumetric charge. This extra charging was used beyond the official purpose, which restricted *cuota* to special construction works. The advantage for the *Comisiones* was that they received the full hundred percent of the fees, and did not have to share them with the higher authorities.

The *Junta* and *Comisiones* in Chancay-Lambayeque decided in 1992, after the management transfer, to introduce payment per volume of water requested to be able to increase the fee recovery. This also enables the collection of the fees already during the irrigation season and not afterwards. Fee recovery was high in both systems. Fee payment was enforced by strictly adhering to the rule that no water turns were given without prior payment. In Jequetepeque, where no individual turns were scheduled during the main part of the rice-irrigation season, the fees were recovered the next irrigation season by denying water to a farmer that had not yet paid the fees of the former year. The exclusion of non-paying water users was made possible because rice nurseries needed water in a narrow time-window because of low temperatures affecting rice yield at the end of the rice-growing period (this structure of technical, environmental and institutional elements enforcing the fee payment was called an 'obligatory point of passage').

Only the sugarcane co-operatives in the head-end of the Chancay-Lambayeque system could not be forced to pay because of their powerful position supported by the government and their location in the head-end of the system.

In Chancay-Lambayeque the water users were charged more or less the volume received at field level. Four factors made this possible: (a) The acceptance by the water users of the legitimacy of a payment per scheduled volume, based on influence of the water users themselves on the amounts to be paid and to some extent the expenditure of the funds. (b) The physical possibility to exclude non-payers. (c) The control by higher levels (ETECOM) on the official payment (and not illegal selling) of water turns. (d) The administration of the water payments of the individual water users and the planning of deliveries of water at different levels in the irrigation scheme with the help of the SARA computer program.

The volumetric payments in Chancay-Lambayeque did have little effect on the re-allocation of water. If water was available without restrictions water users would request the volumes they needed with little consideration for its costs. As the production system for rice was 'high-input – high-output' the extra costs for water were regarded as just any other necessary input (like fertiliser, weeding and agro-chemicals). With the high investments, users would not like to take the risk of reducing their yield by applying insufficient water. To the contrary, the difference in water rights between Chancay-Lambayeque and Jequetepeque was very important to understand the difference in performance of the water delivery and the productivity in water (Perry 1995 comes to a similar conclusion).

In Chancay-Lambayeque had the water use was restricted by the low water availability and the volumetric charging only prevented extreme over-use in water abundant periods (10% more cultivated area due to volumetric payment: see Appendix V). In water scarce periods water was rationed by means of fine-tuned rules, in which market-mechanisms played no role.

The financial situation of the irrigation systems was somewhat vulnerable. The past years fee recovery had been sufficient to operate and maintain the systems well, but the funds were insufficient for an adequate maintenance of the secondary canals. The special rehabilitation projects made up for some of the neglected maintenance while they intervened to repair the damage caused by the 1998 El Niño floods. The *Junta de Usuarios* and their private companies however were able to invest in heavy machinery, save money in an emergency fund, and keep all infrastructure in good operational conditions. Salaries offered were sufficient to attract capable staff. Nevertheless, the financial sustainability of the systems was at risk. First of all, fees collected in Chancay-Lambayeque depend on the amount of water available from the river. In dry years less water can be sold, resulting in less income. Second, the water users each year are very reluctant to increase the fees (even if just to compensate for the inflation). This leaves no room for the *Comisiones de Regantes* to do some extra investments or save funds for future needs.

8.2 Reflections on the theoretical framework and methodologies used

The basis of the analyses of the volumetric water control was that it comprises three dimensions: allocation (and scheduling), delivery and charging (and recovery). At times it proved difficult to separate the three dimensions in the description of the practices of water management. This because the three dimensions are very much related and one dimension cannot be understood without the other two. However, the distinction is still regarded as useful because it separates different aspects on which more or less independent decisions can be taken and rules put in place. For example, one can allocate water per volume but charge a flat fee.

In this research it was assumed that actual water delivery is based on the schedule for the water turns, and that the schedule is based on water allocation rules. For the Chancay-Lambayeque systems this proved to be a workable assumption. The close relation between official water allocation and actual water supply at field level explained the importance and number of conflicts about water allocation. It also directed the research to situations where the delivery was not exactly to the schedule (e.g. water theft, *bajas*, *riegos volantes*). As ninety percent of the official schedule materialised in reality it was very relevant to study the processes of water allocation and scheduling. This is contrary to situations in India and Pakistan where water delivery is very different from official water allocation.

The Social Construction of Technology (SCOT) theory focuses on the social construction, social requirements for use, and social effects of technology. The social construction of technology was relevant in Chapter 2. There the historic processes were described by which the present irrigation technology was shaped. Interests of *haciendas*, governments, foreign donors and local water users' organisations each contributed to the shaping of the irrigation infrastructure. The social requirements for use were highlighted especially in Chapter 5. The open canals and different compositions of undershot and overflow gates require certain knowledge and skills to distribute water according to a complicated schedule. Also the reading of water flows from Parshall flumes requires specific knowledge. The social consequences of the irrigation infrastructure are hard to separate from other factors shaping social differentiation. The hydraulic infrastructure concentrates the flow fluctuation in the tail end of the systems. Thus, water deliveries are less reliable in the tail-ends. The lack of water, but also the excess of water, creates certain institutional responses that affect farmers differently.

In addition to irrigation infrastructure also other technologies, like rice-cultivation, were analysed with the SCOT approach. In Chapter 2 the background of the rice varieties was briefly explained. The property of rice to have its yield reduced by low temperatures in the end of the growing season was an important factor in explaining the 'obligatory point of passage' that made the rice growers in Jequetepeque pay their ISF (and helped prevent the expansion of the rice-cropping zone in Chancay-Lambayeque).

Of course, also the SARA computer program was an important technology that enabled a control over money and water flows, had certain requirements for use, and had social effects. It put the control over boards and staff in the domain of ETECOM as this company gathered and analysed the information. The water users had hardly any access to this data, whereas access could have made the accountability of the boards of the *Comisiones* towards the users much stronger.

The Actor-Network theory was used only in a very limited way. The idea of a network of persons, material objects, money and texts that can be mobilised to be functional for an actor was used to point to the fact that coercion of payment of the ISF was made possible by the use of an 'obligatory point of passage' by the water users' organisations. The canals, social control, payment, properties of the rice crop, and water availability, all were used strategically to force the water users to pay. Also in the water distribution, aggregates of material and social components were employed to control water and prevent theft. An important insight is that material components can be substituted by human components and the other way around. For example, extra vigilance can be substituted (partially) by a padlock or 'deep canals'. Villarreal (1994) shows that Actor-Network theory can be used also to look at social networks, structures of authority and power relations. This was not done in this study, but might be a useful way to explore the management of irrigation systems.

Governance and management was studied using various analytical concepts. To understand the macro-relations between and among the organisations, their domains, power, and rules were studied. The identification of domains proved useful to analyse the tasks, responsibilities, dependencies, obligations and territories of the various sub-organisations of the water users' organisation, private companies and the different local governmental organisations.

Currently much used and debated is the New Institutional Economics approach presented by among others Ostrom (1990). The approach of Ostrom is interesting as it discards the State and market as only forces that can regulate use and conservation of natural resources. She stresses the capabilities of local communities to come to long-enduring institutions for resource management. However, as she starts from basic game-theories and does not differentiate between powerful and less powerful actors within and outside the communities she does not articulate the role of power differences and mechanisms of coercion that are crucial to the understanding of the practices of shaping and maintaining institutions. This becomes also clear in her widely used list of eight 'design principles for long-enduring institutions'. Social power differences play no role here. Nevertheless, many concepts used by Ostrom are useful and were also used in this thesis: mutual monitoring, local refinement of institutions, importance of possibility to monitor and sanction effectively, low-cost local arenas for conflict management, costs of monitoring and punishment of rule violation, and the difference between rules for governance and rules for operational management.

The analysis of social power is central to the understanding of the relations between the water users, water users' organisations and local governmental organisations. With the formal regulations alone little can be said about the actual dynamic processes that shape water allocation, scheduling and delivery. Power and mechanisms of coercion (e.g. obligatory points of passage) proved to be essential to understand why certain rules are adhered to and others not.

In volumetric water control the relations between the water users (as client) and the water users' organisations and private company (as provider of water) are important. It proved to be useful to make a clear distinction between: (1) responsiveness, (2) accountability and (3) participation in decision making. All are relations that involve a power balance between the involved parties. The relations between the 'provider' and the 'client' are, however, very different. Responsiveness means the provider responds to preferences of the client and provides flexible services on request from them (for example a super-market might sell chocolate bars in response to a demand, but clients do not have a right to buy chocolate bars). The clients have no (or very little) power to enforce responsiveness, because the provider is a monopolist. The *Comisiones* were quite responsive to the water users in the water scheduling, albeit only in water abundant periods. Farmers could request how much and when to receive water.

Accountability in provider-client relations refers to the degree to which the clients can monitor and enforce the service agreements made on the delivery of the service (and/or goods). This requires transparency of management and monitoring of the service delivery. In western societies 'consumer organisations' and news media are often more important in agreement enforcement than official rules and court systems. In case of a monopolist provider for irrigation water, the power of the clients to enforce the agreed delivery is very important. The service agreements were quite clear and detailed (when, how much water against what payment). The water users had power because of institutional relations between the water users and the *Comisiones*: elections of the boards, inspections by the *presidente,* and social control of the users towards the operators.

Participation in decision making is different from responsiveness and accountability. The degree of direct participation by the water users in decisions made by the *Comisiones*, *Junta* and ATDR was quite low. By means of elections of the board of the *Comisión de Regantes* the water users can indirectly influence the management of the boards, but elections were cancelled and in general elections alone guarantee little involvement of the users in the management. The other official way to exert influence on decision making by the boards were the General Assemblies. During the meetings of the General Assemblies, however, few users participated actively. The lack of transparency by the board inhibited also a full participation of the water users. Users resorted much more to informal participation in decision making of the board. Users would verbally and/or on paper ask for certain changes in the infrastructure, change of personnel, or claim water for their crops. They would do that individually or in groups. Sometimes these groups gathered in the office of the *Comisión* to exert power on the board. Sometimes the users turned to external means to exert power on the boards to influence the management of the boards: like radio broadcasts and local newspapers. In the end it can be concluded that the informal participation was relatively high compared to other large-scale irrigation systems in the world. This relative high degree of informal participation should be seen in the light of what was called the 'participation dilemma' in section 1.5.4.

The basis for the field research was a comparative research. Water management in two irrigation systems was studied to assess effects of different modes of water allocation, scheduling, delivery and charging. However, as explained also in Chapter 1, the problem is that causes and effects cannot be determined because a complexity of many factors mutually influence each other, and it is not research under 'laboratory' conditions where all but one factors can be kept constant. In case of Chancay-Lambayeque and Jequetepeque the effect of volumetric payment was hard to assess because overall water availability of both systems differed much. Nevertheless, the comparative design of the research yielded many interesting insights in the 'styles' of management and diverse options for volumetric control.

In the field study a variety of research methods was used. The two main important methods were on the one hand interviews, and on the other hand water flow measurements. Other methods included literature and archive research, standard questionnaires, yields measurements, and more general observations of fields, canals and meetings.

Interviews were held with key informants of the different sub-organisations. Most engineers of the *Junta* and selected *Comisiones* were interviewed several times. Also water users in the selected tertiary blocks were repeatedly encountered in the field. After the initial stage of exploring more detailed issues and cases were followed up by specific observations, data gathering and interviews. In this respect meetings on water allocation and scheduling were important. In addition, several cases of dispute and conflict were studied. The use of disputes and conflicts - to assess issues of contradicting interests, power relations and rules used - proved to be fruitful. The arguments put forwards by the parties in the conflict revealed the bodies of normative and legal institutions they considered useful to legitimise their claims. Interestingly, also technical arguments played an important role in legitimising certain claims. However, it proved very difficult and time-consuming to follow-up on the cases of conflict. It was hard to locate the involved actors, and most conflicts had long histories and were not resolved at the time of study. Quite different viewpoints and 'facts' would be exposed when interviewing different stakeholders in the conflict, making it hard to construct one consistent view on what happened.

To assess the water delivery to the water users a water flow measurement programme was conducted. The main indicator was the Delivery Performance Ratio (DPR) that compares the actual flow with the programmed flow. In the case of Chancay-Lambayeque this was more useful than the Relative Water Supply (RWS) as this evaluates the actual water supply against the crop water requirements. In Chancay-Lambayeque the farmers themselves determine how much water they want to buy (in water abundant periods), and they also have particular strategies to adhere or not to the official cropping pattern. This makes it difficult to use the RWS as an evaluation criterion. The RWS would give an indication of how much water the farms buy (and not how well the agency provides water to meet crop needs). Furthermore, a choice would have to be made between the official and the actual crop water requirements. Taking the official crop water requirement would say little about how well the actual crops were irrigated (as the farmers might grow different areas with different crops). Taking the actual cropping pattern would perhaps reveal a lack of water (but that would reflect the strategy of the farmers to grow more land with more water requiring crops, and not a deficiency in the provision of the water the farmers are entitled to). Thus while the RWS tells you something about the allocation, delivery and farmers strategies, the DPR tells you only something about the materialisation of the scheduled water flows. However, the RWS was calculated to indicate the level of water stress experienced by the water users, as this influences the pressure on the operators.

The Hydraulic Flexibility (F) was used to assess the sensitivity of the offtakes to flow changes. The more 'sensitive' offtakes were chosen to assess the DPR, because a good delivery performance in these more 'difficult' offtakes would suggest a good delivery performance also in less sensitive offtakes. Nevertheless, it should be stressed that the measurement programme covered only a very small part of the total systems, and was conducted only in one season, making all conclusions only indicative and not providing a complete evaluation of the water delivery.

The water flow measurement programme served more purposes than just assessing the water delivery performance. The flow measurements required a daily presence at fixed (strategic) points along the canals during the complete irrigation season. The repeated presence was very useful to follow up on happenings related to water distribution. The daily presence in the field allowed for many informal contacts with *sectoristas*, *canaleros*, *tomeros*, *repartidores*, *presidentes* of *Comités de Canal* and water users. The observations of the encounters between the staff and the water users were very informative and the fact that you measure water gives further impetus to the discussions between those actors. If you spend some hours every day along the canals of the same tertiary block for flow measurements you gain many insights into the complicated social relations. At the same time it allows you to observe the crop and irrigation practices of the farmers, the sedimentation and cleaning of the canals, and the salinisation and waterlogging processes during the irrigation season.

8.3 Implications for interventions

The insights gained in the study on the management of the irrigation systems on the North Coast of Peru have some implications for interventions in joint managed large-scale irrigation systems in general. First of all the complexity of the organisations and the refinement of the institutions imply that simple regulations for authority, decision-making, operational tasks and financial conduct will probably not function. Institutions are tuned to deal with the local diversities in the material, social and economic environment. Furthermore, the institutions are shaped by, and themselves shaping, social power relations. Intervention strategies should deal with that to be effective. For example the nature of the private companies of the *Juntas de Usuarios* require a different type of thinking about water users' associations. The social power involved in the checks and balances between the different governmental, commercial and water users' organisations shaped relations of accountability. Interventions should pay attention to the official rules needed to facilitate effective and workable relations of accountability.

The study shows that the staff of the *Comisiones* and *Juntas* is very skilled and experienced in the tasks they perform. Although most have had little formal training (in the field they are working in), they gained much knowledge and skills while performing their tasks. 'Perverse incentives' make that they do not always serve the interests of their organisation, the water users, and water use efficiency in general. But that should not be confused with a lack of knowledge and skills. Some of the 'perverse activities' can only be performed so well just because of this knowledge and skills. This implies that training programmes to increase knowledge and skills should not underestimate the knowledge and skills, and should address only specific gaps of the staff and board members (on request of them).

The good water delivery performance with the alleged 'nightmare' infrastructure (open canals, undershot gates, etc) and operational conditions (irregular river supply and on request scheduling) implies that modernisation of irrigation infrastructure to increase water delivery performance should be reconsidered. That is not to say that improvements in infrastructure are unnecessary, but it signifies that other factors might be more constraining and that improvement of the infrastructure will not automatically lead to better water distribution.

8.4 Suggestions for further research

This study is an interdisciplinary research. It is clear that studying volumetric water control cannot be done from a mono-disciplinary viewpoint. Technical, social or economic factors alone are insufficient to understand the shaping of control by the complex organisations over water and money flows. However, a perhaps intrinsic drawback of interdisciplinary research is that the many factors are only analysed somewhat superficially. Many aspects could be studied in much more depth: hydraulics of large-scale open canal systems; rice growth under water stress; history of allocation and scheduling regulations; sociology of the perception of water users of the IMT process; juridical aspects of conflict resolution by the local governmental organisations; or economics of asset management of water users' associations.

Each of the more specialised fields of research could contribute to the understanding of the complex interrelationships between the various factors. Disciplinary research however should start from the interdisciplinary framework and aim to contribute to this framework.

More specifically, five (partly overlapping) fields for further research can be formulated drawing on the findings in the previous chapters.

1. 'Role of rules': Some laws and regulations imposed on the water users' organisations and local governmental organisations were implemented and used to set governance relations and practices of daily management. It was not so much legal pluralism (more than one legal system defining rules on the same issues), but much more 'organisational pluralism' and local interpretation and refinement of the official -but general - rules. This leads to questions of how national laws, but also regulations of water users' organisations can be crafted to be effective (whatever their aims are). If they just legalise and legitimise existing practices socially powerful people will most probably gain more power. But promulgating rules that go counter to the existing power relations are destined to be ignored. Law influences, and is influenced by, social power. It seems networks of alliances of existing 'counter forces' might be better mobilised if proper laws and regulations are promulgated. How this works in the case of water management is an interesting field of research.

2. 'Comparative study of volumetric control practices in Latin America'. The success of the Chancay-Lambayeque systems in volumetric control contrasts with many cases studies from all over the world where control over allocation, scheduling, delivery and charging was less successful. However, some case studies from Latin America suggest that more large-scale irrigation systems can be found in this region that function well (in the technical-organisational way, perhaps not regarding equity or environmental sustainability). In Argentina (Murray-Rust and Snellen 1993), and Mexico (Kloezen and Garcés-Restrepo 1998, Levine *et al.* 1998) systems with similar infrastructure and management can be found that suggest that control over water is more effective than often presumed.

3. 'Comparative study of accountability and rule-of-law between Latin America and Asia'. Somewhat more rule-of-law seems to exist in the North Coast of Peru in comparison with large-scale systems in Pakistan and India. Although water rights are highly contested they seem to be more a guarantee for actual water supply in Latin America than in Asia. Why and how these differences between Latin America and Asia occur would be and interesting study. Especially when focussing on responsiveness, accountability and participation in decision making of the water users. Has the IMT model in Latin-America created more user-friendly systems? How is social equity affected? And why do the differences occur?

4. 'Role of irrigation infrastructure': Precise volumetric water delivery proved to be possible with open, unlined, canal and manually operated, undershot gates. The skills of the operators and their accountability towards the water users resulted in an unexpectedly good delivery of the programmed volumes. The question is now, what would happen if the infrastructure would be 'modernised'? Modernisations like buried pipes, automatic or automated gates, downstream control and measurement structures are promoted to improve delivery performance. In the light of the presented study it becomes interesting to see what happens with the skills, accountability, and related performance if the 'human element' in water distribution is decreased.

5. 'A framework to understand water delivery'. The framework presented in Chapter 5 on the factors that influence water delivery performance could be improved. This could be done by looking systematically for the way in which certain factors influence water delivery performance in other irrigation systems around the world. The identified factors could be further detailed. For example, by looking at the exact relation between the various factors and their influence on the delivery in certain contexts.

Finally, to conclude this thesis, two quotes are given. One to illuminate the long history of the debate on volumetric water control. The other to show the enormous refinement of rules regarding water allocation and scheduling found in practice. They illustrate, like the rest of thesis, that simple models of institutions for water allocation, scheduling, delivery and charging cannot grasp the reality of practices found around the world regarding the use and conservation of world's most precious liquid.

Mr. Erry in a debate during the Punjab Engineering Congress in 1936 on volumetric charging of water :

"[Erry] could find no justification for postponing what he regarded as a most valuable reform, the development of that progress which had taken place from a mere hole in the bank of a Distributary to Mr. Crump's A.P.M. but had so far stopped short there. It was ***high time*** *that the old fashioned crop acreage system of assessment which had outgrown its utility was discarded and the logical and scientific volumetric assessment was substituted."*
(Erry 1936:28c, emphasis added)

Water allocation rules in a contemporary (but ancient) indigenous '*galería*' (horizontal well known as 'qanat' in the Middle East and Africa) irrigation system in Mexico (note the mix of market and very refined regulations):

"There are two kinds of allocation: allocation or share distribution that represents the original investment in the association (acciones), and the hourly distribution system within and outside the monthly cycles (tandas). [...] both acciones and tandas are bought and sold. [...] The irrigation water from each galería system is divided among the members in a thirty-day rotation or cycle of irrigation turns. The members receive water during specific time periods every month, depending on the amount of time to which they are entitled. The minimal unit for the measurement of water is one hour of the total flow of a galería system. Hence, there are 24 irrigation hours in a day and a night, and every month consists of thirty 24-hour irrigation periods, or 720 hours. Every month repeats the basic monthly turn schedule. The amount of time one farmer has in a month, the number of farmers entitled to water, the unequal length of the months, and the cyclical occurrence of leap years are incorporated into the system. [footnote: ....] The five twenty-four hour periods on the thirty-first of May, July, August, October, and February 29 in a leap year are not part of the thirty-day distribution cycle and are distributed as separate acciones. The total number of irrigation hours is 8,760 in a nonleap year and 8,784 in a leap year. A socio's tanda is the number of continuous hours that he or she is entitled to, and socios may have many tandas in a month cycle. All the associations keep a list of tandas, called lista de tandeo, so that each member knows to the minute when his or her tandas begin and end."
(Enge and Whiteford 1989:114)

References

Alberts, T., 1983, *Agrarian reform and rural poverty: A case study of Peru*, A Westview Replica Edition, Westview Press, Boulder, Colorado.

Allan, T., 1999, "Productive efficiency and allocative efficiency: Why better water management may not solve the problem", in: *Agricultural Water Management*, Vol. 40, pp. 71-75.

Alva, C.A., J.G. van Alphen, A. de la Torre and L. Manriqie, 1976, *Problemas de drenaje y salinidad en la Costa Peruana*, ILRI, Bulletin 16.

Alva, W., 1994, *Sipan: Descubrimineto e investigación*, Cervecería Backus & Johnston, Lima, Peru.

Ankum, P., 1992, "Desired behaviour of irrigation systems", in: J. Feyen, E. Mwendera and M. Badji (eds.) *Advances in planning, design and management of irrigation systems as related to sustainable land use*, pp.245-254.

[anonymous] 1929, *Anales del primer congreso de irrigación y colonización del Norte*, 12-17 October 1928, 4 Volumes, Lima.

Bachrach, P. and M.S. Baratz, 1962, "Two faces of power", in: *American Political Science Review*, Vol. 56, pp. 947-952.

Bardhan, P., 1989, "Alternative approaches to the theory of institutions in economic development", in: Bardhan (ed.), *The economic theory of agrarian institutions*, Oxford University Press.

Bardhan, P., 1991, "On the concept of power in economics", in: *Economics and Politics*, Vol. 3, No. 3, November, pp. 265-277.

Bauer, C.J., 1997, "Bringing water markets down to earth: The political economy of water rights in Chile, 1976-95", in: *World Development*, Vol. 25, No. 5, pp.639-656.

Bauer, C.J., 1998, *Against the current: Privatization, water markets, and the state in Chile*, Kluwer Publishers, Dordrecht, The Netherlands.

Bautista, E., J.A. Reprogle, A.J. Clemmens, W. Clyma, A.R. Dedrick and S.A. Rish, 2000, "Water delivery performance in Maricopa-Stanfield Irrigation and Drainage District", in: *Irrigation and Drainage Systems*, Vol. 14, pp. 139-166.

Benda-Beckmann, F. von, 1989, "Scape-goat and magic charm: Law in development theory and practice", in: *Journal of Legal Pluralism*, Vol. 28, pp.129-148.

Benda-Beckmann, F. von, 1992, "Introduction: Understanding agrarian law in society", in: F. von Benda-Beckmann and M. van de Velde (eds.): *Law as a resource in agrarian struggles*, Pudoc, Wageningen, The Netherlands.

Benda-Beckmann, F. von, K. von Benda-Beckmann and H.L.J. Spiertz, 1996, "Water rights and policy", in: *Recht der Werkelijkheid*, 1996, pp.77-99.

Benda-Beckmann, K, von, 1981, "Forum shopping and shopping forums", in: *Journal of Legal Pluralism*, Vol. 19, pp. 117-159.

Bentum, M. van, 1995, *Water, werk en waterwerken, De ontwikkeling van irriagatietechnologie in het stroomgebied van de Segura, Zuidoost-Spanje*, PhD thesis, Wageningen Agricultural University.

Bentum, R. van, and I.K. Smout, 1994, *Burried pipelines of surface irrigation*, Intermediate Technology Publications, London.

Bijker, W.E., 1987, "The social construction of bakelite: Towards a theory of invention", in: W.E. Bijker, T.P. Hughes and T.J. Pinch (eds.), *The social construction of technological systems: New directions in the sociology and history of technology,* MIT Press, Cambridge, pp. 159-87.

Bijker, W.E., 1993, "Do not despair: There is life after constructivism", in: *Science, Technology & Human Values,* Vol. 18, No. 1, Winter, pp. 113-138.

Black, D. (ed.), 1984, *Toward a general theory of social control,* Volume 2, Selected Problems, Academic Press, Orlando.

Boelens, R., 1998, "Collective management and social construction of peasant irrigation systems: a conceptual introduction", in: R. Boelens and G. Dávila (eds.): *Searching for equity, conceptions of justice and equity in peasant irrigation,* pp. 81-99, Van Gorcum, Assen, The Netherlands.

Boelens, R, and P. Hoogendam, 2002, "The yapa. Water rights, power and empowerment", in: R. Boelens and P. Hoogendam (ed.): *Water rights and empowerment,* Koninklijke Van Gorcum, Assen, The Netherlands.

Bolding, A., P.P Mollinga and K. van Straaten, 1995, "Modules for modernisation: Colonial irrigation in India and the technological dimension of agrarian change", in: *Journal of Development Studies,* Vol 31, No. 6, pp. 805-844.

Bos, M.G., 1978, *Discharge measurement structures,* (Second ed.), International Institute of Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands.

Bos, M.G. and D.H. Murrey-Rust, D.J. Merrey, H.G. Johnson and W.B. Snellen, 1994, "Methodologies for assessing performance of irrigation and drainage management", in: *Irrigation and Drainage Systems,* No.7, pp. 231-261.

Boss, M., 1996, *Acceso a agua de riego: Discrepancias entre teoría y práctica, estudio de caso en el subsector de riego de Sasape,* MSc thesis (unpublished), Wageningen Agricultural University, The Netherlands.

Bottrall, A.F., 1981, *Comparative study of the management and organization of irrigation projects,* World Bank Staff Working Paper, No. 458, Washington.

Bromley, D.W., 1982, *Improving irrigated agriculture: Institutional reform and the small farmer,* World Bank Staff Working Papers, No. 531, Washington.

Bruijn, K. de, 1999, *Análisis del pronóstico hídrico y su relación con la planificación de la campaña agrícola,* Libro de Trabajo 10, IMAR Costa Norte, Chiclayo, Peru.

Brüning, E., 1923, *Reglamentación de las aguas del Taymi, Estudios mongráficos del departemento de Lambayeque,* Fasciculo IV, reproduced in: J.M. Vreeland, 1989, Sociedad SICAN, Cerveceria del Norte, Chiclayo, Peru.

Burga, M., 1976, *De la encomienda a la hacienda capitalista, El valle del Jequetepeque del siglo XVI al XX,* Instituto de Estudios Peruanos.

Burns, R.E., 1993, "Irrigated rice culture in monsoon Asia: The search for an effective water control technology", in: *World Development,* Vol, 21, No. 5, pp. 771-783.

Callon, M, J. Law and A. Rip (eds.), 1986, *Mapping the dynamics of science and technology: Sociology of science in the real world,* Macmillan, London.

Carpio, C. and P. Mejia, 1996, *Evaluacion campaña agricola del valle Jequetepeque, Periodo 1994-1995, Proyecto Especial Jequetepeque-Zaña,* Dirección de Desarrollo Agricola y Medio Ambiente, Ministerio de la Presidencia.

Carrasco, C., L. Sáez and J. Mejía, 1993, "Inventario y evaluación de los recursos agua, suelo y de infraestructura de riego", in: *GPER, Gestion del Agua y Crisis Institutional, Un análisis multidisciplinario del riego en el Perú,* ITDG, SNV, Lima, Peru, pp.27-58.

Castillo, L. del, 1994, "Lo bueno, lo malo, y lo fue de la legislación de aguas", in: *Debate Agrario*, No. 18, Cepes, Peru, pp. 1-20.

Cerdán y Portero, A., 1793, "Disertacion sobre las aguas que riegan los valles de Lima", reproduced in: *Antiguo Mecurio Peruano*, 1861, pp. 90-123.

CESDER, 1995, *Cuenca de Jequetepeque*, CEDEPAS, Cebemo/Vastenaktie.

Chincay, L. and P. Sijbrandij, 1999, *Intervención en la gestión del agua de riego: La experiencia del IMAR en el valle Chancay-Lambayeque*, Libro de Trabajo 11, IMAR Costa Norte, Chiclayo, Peru.

Cleaves, P.S. and M.J. Scurrah, 1980, *Agriculture, bureaucracy and military government in Peru*, Cornell University Press, Ithaca.

Clegg, S.R., 1989, *Frameworks of power*, Sage Publications, London.

Clemmens, A.J., A.R. Dedrick, W. Clyme and R.E. Ware, 2000, "On-farm system performance in the Maricopa-Stanfield Irrigation and Drainage District area", in: *Irrigation and Drainage Systems*, No. 14, pp.93-120.

Clemmens, A.J., G. Sloan and J. Schuurmans, 1994, "Canal-Control Needs: Example", in: *Journal of Irrigation and Drainage Engineering*, Vol. 120, No. 6, Nov/Dec 1994.

Collin Delavaud, C., 1984, *Las regiones costeñas del Peru septentrional: Ocupacion humana, esarrollo regional*, Centro de investigacion y promocion del campesinado, Pontificia Universidad Catolica del Peru.

Cook, N.D., 1981, *Demographic collapse: Indian Peru, 1520-1620*, Cambridge University Press, Cambridge.

Cosgrove W.J. and F.R. Rijsberman, 2000, *World water vision: Making water everybody's business*, Earthscan Publications, London.

Crawford, S., 1988, *Mayordomo, Chronicle of an acequia in northern New Mexico*, Second University of New Mexico Press.

Crouch, D.P., 1996, "Water technology in New Spain", History Seminar (R14), *International Commission of Irrigation and Drainage, Sixteenth Congress*, Cairo, pp. 259-295.

Crump, E.S., 1922, *A note on the moduling of irrigation channels* (Typescript).

Deere, C.D. and M. León, 1998, *Reforma agraria y contrarreforma en el Perú: hacia un análisis de género*, Ediciones Flora Tristán, Lima, Peru.

Donnan, C.B., 1990, "Masterworks of art reveal a remarkable pre-Inca world", in: *National Geographic*, June, Vol. 177, No 6, pp. 17-33.

Dourojeanni, A. and M. Molina, 1983, "The Andean peasant, water and the role of the State", in: *CEPAL Review*, April.

Eling, H.H., 1978, "Interpretaciones preliminares del sistema de riego antiquo de Talambo en el Valle de Jequetepeque Peru", in: R. Matas (ed.), *El Hombre y la Cultura Andina*, Lima, pp. 401-418.

Eling, H.H., 1987, "The rustic boca toma: Traditional hydraulic technology for the future", in: D.L. Browman (ed.), *Arid land use strategies and risk management in the Andes: A reginal anthropological perspective*, pp. 171-193, Westview Press, Boulder.

Erry, P.K.R., 1936, "Water distribution assessment of revenue at volumetric rates", in: *Proceedings of the Punjab Engineering Congress*, Paper No. 188, p.19-28k.

FAO, 1984, *Crop water requirements*, FAO Irrigation and Drainage Paper 24, (reprint from 1977) Rome.

FAO, 1996, *Food production: The critical role of water*, draft document prepared for the World Food Summit, FAO, Rome.

Farrington, I., 1974, "Irrigation and settlement patterns: Preliminary research results from the North Coast of Peru", in: T.E. Dowing and McG. Gibson (eds.), *Irrigation's impact on society*, Anthropological papers of the University of Arizona, No. 25, The University of Arizona Press, Tucson, pp. 83-94.
Farrington, I.S., 1978, "Irrigación prehispanica y establecimientos en la Costa Norte del Peru", in: R. Ravines (ed.), *Tecnologia Andina*, pp. 117-128.

Garcés-Restrepo C. and J. Guerra-Tovar, 1999, *Consideraciones sobre impacto ambiental por efecto de las obras de regadio en el distrito de riego Chancay-Lambayeque, Perú*, IWMI, Serie Latinomericana, No. 7, Mexico.

Geertz, C., 1972, "The wet and the dry: Traditional irrigation in Bali and Morocco" in: *Human Ecology*, Vol. 1, No. 1, pp. 23-39.

Gelles, P.H.,1994, "Channels of power, fields of contention: The politics of irrigation and land recovery in an Andean peasant community", in: W.P. Mitchell. and D. Guillet (eds.): *Irrigation at high altitudes: The social organization of water control systems in the Andes*, American Anthropological Association.

Geijer, J.C.M.A., M. Svendsen and D.L. Vermillion, 1995, *Transferring irrigation management responsibility in Asia: Results of a workshop*, Short Report Series on Locally Managed Irrigation, Report No. 13, FAO/IIMI Expert Consultation on Irrigation Management Transfer in Asia, Bankok and Chiang Mai, 25-29 September 1995.

Gerbrandy, G. and P. Hoogendam, 1998, *Aguas y acequias: Los derechos al agua y la gestión campesina de riego en los Andes bolivianos*, Plural Editors, Cochabamba, Bolivia.

GFA-Jequetepeque, 1999, Unpublished internal report, Gesellschaft für Agrarprojekte, Germany.

GFA-Tinajones, 1999, Unpublished internal report, Gesellschaft für Agrarprojekte, Germany.

Glick, T.F., 1996, *Irrigation and hydraulic technology: Medieval Spain and its legacy*, Variorum Collected Studies Series, No. 523, Ashgate, Hampshire, Great Britain.

Godaliyadda, G.G.A., D. Renault, H.M. Hemakumara and I.W. Makin, 1999, "Strategies to improve manual operation of irrigation systems in Sri Lanka", in: *Irrigation and Drainage Systems*, Vol. 13, pp.33-54.

Gonzales Zúñiga, A.G., 1985, "Cooperativismo agrario y parcelacion en la costa del Peru", in: *Las parcelaciones de las cooperativas agrarias del Perú*, Solidardad, Chiclayo, Peru, pp. 75-142.

Goussard, J., 1996, "Interaction between water delivery and irrigation scheduling", in: *Irrigation scheduling:From theory to practice*, Water Reports 8, FAO, Rome, pp. 263-272.

Grimble, R.J., 1999, "Economic instruments for improving water use efficiency: Theory and practice", in: *Agricultural Water Management*, Vol. 40, pp. 77-82.

Grist, D.H., 1986, *Rice*, (6th ed.), Longman, London.

Guaman Poma de Ayala, F., 1956-1966, *Nuevo coronica i buen gobierno*, L. Bustios Galvez (ed.), 3 volumes, Imprenta Grafica Industrial, Lima, Peru.

Guillet, D., 1994, "Canal irrigation and the state: The 1969 water law and irrigation systems of the Colca Valley of Southwestern Peru", in: W.P. Michell and D. Guillet (eds.), *Irrigation at high altitudes: The social organization of water control systems in the Andes*, Society for Latin American Anthropology publication series, Vol. 12.

Guillet, D., 2000, "Water property rights and resistance to demand management in northwestern Spain", in: B.R. Bruns and R.S. Meinzen-Dick (eds.) *Negotiating Water Rights*, IFPRI, New Delhi, pp. 222-244.

Guillet, D. and W.P. Mitchell, 1994, "Introduction: High altitude irrigation", in: W.P. Michell and D. Guillet (eds.), *Irrigation at high altitudes: The social organization of water control systems in the Andes*, Society for Latin American Anthropology publication series, Vol. 12.

Halsema, G.E. van, and D.H. Murray-Rust, 1999, "Hydraulic flexibility as a computational tool for the determination of operational strategies", in: *Proceedings of 1999 USCID Workshop; Modernization of Irrigation Water Delivery Systems*, USCIDI, Denver, pp.663-679.

Hård, M., 1993, "Beyond harmony and consensus: A sociol conflict approach to technology", in: *Science, Technology & Human Values*, Vol. 18, No. 4, Autumn, pp. 408-432.

Heywood, A., 1994, *Political ideas and concepts: An introduction*, MacMillan, Basingstroke.

Hidrogo Contreras, C.R., 1996, *Caracterización de las unidades productivas del valle Chancay-Lambayeque*, Libro de Trabajo 5, IMAR Costa Norte, Chiclayo, Peru.

Hocquenghem, A.M., 1998, *Para vencar la muerte, Piura y Tumbes: Raíces en el bosque seco y la Selva Alta en Horizontes el Pacífico y en la Amazonia*, Traveaux de l' Institut Français d'Étude Andines, Nr. 109, CNRS, Paris and IFEA and INCAH, Lima, Peru.

Hoffman, J., 1995, *Beyond the state, An introductory critique*, Policy Press, Cambridge.

Hofwegen, Van, P., 1996, "Social, cultural, institutional and policy constraints", in: *Irrigation scheduling: From theory to practice*, Water Reports 8, FAO, Rome, Proceedings of the ICID/FAO Workshop on Irrigation Scheduling, Rome 12-13 September 1995, pp. 323-333.

Horst, L., 1996, "The discrepancy between irrigation scheduling and actual water distribution: an analysis and suggestions for possible solutions", in: *Irrigation scheduling: From theory to practice*, Water Reports 8, FAO, Rome, pp. 297-304.

Horst, L., 1998, *The dilemmas of water division: Considerations and criteria for irrigation system design*, Colombo, International Irrigation Management Institute, Sri Lanka.

Horst, L., 1999, "The failure of adjustable irrigation technology, the options for change and the consequences for research". in: *Agricultural Water Management*, Vol. 40, No. 1. pp.101-106.

Horwitz, A. V., 1990, *The logic of social control*, Plenum Press, New York.

Huber, S., 1990, "The Peruvian land reform and the position of rural women", in: *Journal of Legal Pluralism*, No. 30-31, pp. 165-222.

IMAR Costa Norte, 1997a, *Plan maestro para la cuenca hidrográfica Chancay-Lambayeque: Avances metodológicos*, Libro de Trabajo 7, IMAR Costa Norte, Chiclayo, Peru.

IMAR Costa Norte, 1997b, *Gestión del agua de riego en el valle Chancay-Lambayeque: Situación actual*, Libro de Trabajo 8, IMAR Costa Norte, Chiclayo, Peru.

INADE, 1998, *Evaluación de los principales aspectos productivos en el desarrollo de la campaña agricola, periodo 1996-1997, Valle Jequetepeque*, Ministerio de la Presidencia, Lima, Peru.

INRENA, 1997, *Ordenamiento del sistema de gestión de los recursos hídricos cuenca Chancay-Lambayeque*: Informe principal, Ministerio de Agricultura, Lima, Peru.

Johnson, S.H., D.L. Vermillion and J.A. Sagardoy, 1995, *Irrigation management transfer*, Selected papers from the International Conference on Irrigation Management Transfer, Wuhan, China, 20-24 September 1994, Water Reports 5, IIMI, FAO.

Keith, R.G., 1976, *Conquest and agrarian change: The emergence of the hacienda system on the Peruvian Coast*, Harvard Historical Studies 93, Harvard University Press, Cambridge.

Keller, J., 1986, "Irrigation system management", in: K.C. Nobe and R.K. Sampath (eds.): *Irrigation in developing countries*, Chapter 11, Westview Press, Boulder.

Kloezen, W.H., 1998, "Water markets between Mexican water user associations", in: *Water Policy*, Vol. 1, pp.437-455.

Kloezen, W.H. and C. Garcés-Restrepo, 1998, *Assessing irrigation performance with comparative indicators: The case of the Alto Rio Lerma Irrigation District, Mexico*, IWMI, Research Report No. 22, Colombo, Sri Lanka.

Kloezen, W.H. and P.P. Mollinga, 1992, "Opening closed gates: Recognizing the social nature of irrigation artefacts", in: G. Diemer and J. Slabbers (eds.), *Irrigators and engineers, Essays in honour of Lucas Horst*, Thesis Publishers, Amsterdam, pp. 53-63.

Kosok, P., 1958, "El valle de Lambayeque", in: *Actos y trabajos del II Congreso Nacional de Histroria del Perú, Epoca Pre-hispanica*, 4 al 9 de Agosto, Volumen I, Centro de Estudios Historico Militares, Lima, Peru, pp. 49-65.

Kosok, P., 1965, *Life, land and water in ancient Peru*, PhD dissertation, Cornell University, Long Island University Press.

Kuper, M., 1997, *Irrigation management strategies for improved salinity and sodicity control*, PhD thesis, Wageningen Agricultural University.

Kus, J.S., n.d., "Recent research on pre-Hispanic agriculture in coastal Peru".

Kus, J.S., 1984, "The Chicama-Moche canal: Failure or success? An alternative explanation for an incomplete canal", in: *American Antiquity*, Vol. 49, No. 2, April, pp. 408-415.

Lamaddalena, N., G. Ciollaro and L.S. Pereira, 1995, "Effect of changing irrigation delivery schedules during periods of limited availability of water", in: Agricultural Eningeering Resources, Silsoe Research Institute, No. 61, p.261-266.

Lankford, B.A. and J. Gowing, 1996, "Understanding water supply control in canal irrigation systems", in: P. Howsam and R.C. Carter (eds.), *Water policy: Allocation and management in practice, Proceedings of International Conference on Water Policy, held at Cranfiend University, 23-24 September 1996*, E&FN Spon, London.

Larrea, E. and F. Ugaz, 1999, *Tarifa del agua de riego sistema Tinajones*, unpublished report IMAR Costa Norte, Chiclayo, Peru.

Latour, B., 1995, "The door must be either open or shut: A little philosophy of techniques", in: A. Freenberg and A. Hannay (eds.), *Technology and the politics of knowledge*, Indiana University Press, Bloomington, pp. 272-281.

Law, J., 1992, "Notes on the theory of the Actor-Network: Ordering, strategy, and hetrogenety", in: *Systems Practice*, Vol. 5, No. 5, pp. 379-393.

Lee, P.S., 1999, "Irrigated agriculture: Adding value through technology and management reform", in: *Agricultural Water Management*, Vol. 40, pp. 89-93.

Levine, D.N., 2000, "On the critique of 'utilitarian' theories of action: Newly identified convergences among Simmel, Weber and Parsons", in: *Theory, Culture & Society*, Vol. 17(1), pp. 63-78.

Levine, G., 1980, "The relationship of design, operation, and management", in: E.W. Coward (ed.): *Irrigation and agricultural development in Asia: Perspectives from the social sciences*, Chapter 3, Cornell University Press, Ithaca.

Levine, G., A. Cruz Galvan, D. Garcia, C. Garcés-Restrepo, and S. Johnson III, 1998, *Performance of two transferred modules in Lagunera Region: Water Relations*, IWMI, Research Report No. 23, Colombo, Sri Lanka.

Lieberson, S., 1992, "Small N's and big conclusions: an examination of the reasoning in comparative studies based on small number of cases", in: C.C. Ragin and H.S. Becker (eds.): *What is a case? Exploring the foundations of social inquiry*, Cambridge University Press.

Lizárraga, C.A., 1929, "El uso del agua", in: *Anales del Primer Congreso de Irrigación y Colonización del Norte*, 12-17 October 1928, 4 Volumes, Lima, pp. 730-743.

Lohmann Villena, G., 1989, Francisco de Toledo, *Disposiciones gubernativas para el Virreinato del Peru 1575-1580*, Tomo II, Escuela de estudios Hispano-Americanos de Sevilla, CSIC, Spain.

Loof, R., C.L. Abernethy and V.S. Mishra, 2000, "Gate operation rules in canal irrigation systems: A case study of Khageri irrigation system, Nepal", in: *ICID Journal*, Vol. 49, No. 3, pp.1-24.

Lukes, S., 1974, *Power: A radical view*, Macmillan, London.

Lynch, B.D., 1988, *Bureaucratic transition, Peruvian government intervention in Sierra samll-scale irrigation*, PhD thesis, Cornell University.

Maass, A. and R.L. Anderson, 1978, *... and the Desert shall rejoice: Conflict, growth, and justice in arid environments*, The MIT Press, Cambridge.

MacKenzie, D. and J. Wajcman (eds.), 1985, *The social shaping of technology*, Milton Keynes, Open University Press.

Malano, H.M. and P.J.M. van Hofwegen, 1999, *Management of irrigation and drainage systems: A service approach*, IHE Monograph 3, A.A.Balkema, Rotterdam.

Mangano, G.V., 1996, "Applicability of irrigation scheduling in developing countries", in: *Irrigation scheduling: From theory to practice*, Water Reports 8, FAO, Rome, pp. 361-366.

Manzungu, E., 1999, *Strategies of smallholder irrigation management in Zimbabwe*, PhD thesis, Wageningen University.

Martin, E.D., 1986, *Resource mobilization, water allocation, and farmer organization in hill irrigation systems in Nepal*, PhD thesis, Cornell University.

Meinzen-Dick, R., 1997, "Farmer participation in irrigation, 20 years of experience and lessons for the future", in: *Irrigation and Drainage Systems*, Vol. 11, pp. 103-118.

Melmed-Sanjak, J.S. and M.R. Carter, 1991, "The economic viability and stability of 'capitalised family farming': An analysis of agricultural decollectivisation in Peru", in: *Journal of Development Studies*, 1991, pp.190-210.

Méndez, N.J., 1998, *Sediment transport in Irrigation Canals*, PhD thesis, Wageningen University, A.A. Balkema, Rotterdam.

Merrey, D.J., 1997, *Expanding the frontiers of irrigation management research: Results of research and development at the International Irrigation Management Institute 1984 to 1995*, IIMI, Colombo, Sri Lanka.

Merriam, J.L., 1992, "The need on the farm for a flexible water supply schedule", in: Proceedings of an international conference, *Advances in planning, design and management of irrigation systems as related to sustainable land use*, Leuven 1992, pp. 147-156.

Mollinga, P.P., 1998a, *On the waterfront: Water distribution, technology and agrarian change in a South Indian canal irrigation system*, PhD thesis, Wageningen Agricultural University.

Mollinga, P.P., 1998b, "Equity and accountability: Water distribution in a South Indian canal irrigation system" in: R. Boelens and G. Dávila (eds.): *Searching for equity: Conceptions of justice and equity in peasant irrig*ation, Van Gorcum, Assen, The Netherlands.

Mollinga, P.P., 2001, "Water and politics: Levels, rational choice and South Indian canal irrigation", in: *Futures*, Vol. 33, pp. 733-752.

Mollinga, P.P., J. Mooij and J. Schakel, 1987, "Wetenschap, technologie en Derde Wereld: Een theoretische inleiding", in: *Revoluon*, Vol. 12, No. 1, pp. 2-47.

Moore, M., 1989, "The fruits and fallacies of neoliberalism: The case of irrigation policy", in: *World Development*, Vol. 17, No. 11, pp. 1733-1789.

Moore, M., 1990, "The rational choice paradigm and the allocation of agricultural development resources", in: *Development and Change*, Vol. 21, pp. 225-246.

Moore, S.F., 1973, "Law and social change: The semi-autonomous social field as an appropriate field of study", in: *Law and Society Review*, Nr. 70, pp. 719-746.

Moseley, M.E., 1974, "Organizational preadaptation to irrigation, the evolution of early water-management systems in coastal Peru", in: T.E. Dowing and McG. Gibson (eds.), *Irrigation's impact on society*, Anthropological papers of the University of Arizona, No. 25, The University of Arizona Press, Tucson, pp. 77-82.

Murray-Rust, D.H. and M. Moore, 1983, *Formal and informal water management systems: Cultivation meetings and water deliveries in two Sri Lankan schemes*, Cornell Studies in Irrigation, No. 2, Cornell University, Ithaca.

Murray-Rust, D.H. and W.B. Snellen, 1993, *Irrigation system performance: Assessment and diagnosis*, IIMI, ILRI and IHE, Colombo, Sri Lanka.

Musch, A., 2001, *The small gods of participation*, PhD thesis, University of Twente, The Netherlands.

Neciosup, M.A., 1999, *Estudio de rentabilidad de cultivos alternativos*, Internal report IMAR Costa Norte, Chiclayo, Peru.

Netherly, P.J., 1987, "Hydraulics and organisation of irrigation in the high civilizations of the Andean region of South America", in: *International Symposium on Water for the Future*, Rome, 6-11 April 1987.

Nuñez Palomino, P.G., 1995, *Law and peasant communities in Peru (1969-1988)*, PhD thesis, Wageningen Agricultural University.

Odar Seminario, L., 1929, "Historia de las instituciones de regadio en los departamentos de Piura y Lambayeque", in: *Anales del Primer Congreso de Irrigación y Colonización del Norte*, 12-17 October 1928, 4 Volumes, Lima, pp. 1150-1155.

Oorthuizen, J., 1998, "Re-engineering space: re-use systems in tail-end struggles", in: *Proceedings CERES seminar 1998*, not published.

Oorthuizen, J. and W.H. Kloezen, 1995, "The other side of the coin: A case study on the impact of financial autonomy on irrigation management performance in the Philippines", in: *Irrigation and Drainage Systems*, No. 9, pp. 15-37.

Oré, M.T., 1989, *Riego y organización: Evaluación histórica y experiencias actuales en el Perú*, ITDG, Lima, Peru.

Oré, M.T., 1998, "From agrarian reform to privatisation of land and water: The case of the Peruvian coast", in: R. Boelens and G. Dávila (eds.): *Searching for equity: Conceptions of justice and equity in peasant irrigation*, pp. 268-278, Van Gorcum, Assen, The Netherlands.

Ortloff, C.R., 1988, "Canal builders of pre-Inca Peru", in: *Scientific American*, December, p.74-80.

Ostrom, E., 1990, *Governing the commons: The evolution of institutions for collective action*, Cambridge, Cambridge University Press.

Oxford Paperback Dictionary, 1988, Oxford University Press, Third Edition.

Perry, C.J., 1995, "Determinants of function and dysfunction in irrigation performance, and implications for performance improvement", in: *Water Resources Development*, Vol. 11, No. 1, pp. 25-28.

Perry, C.J., 2001, "Water at any Price? Issues and options in charging for irrigation water", in: *Irrigation and Drainage*, Vol. 50, pp.1-7.

Plusquellec, H., 1990, *The Gezira irrigation scheme in Sudan: Objectives, design, and performance*, World Bank Technical Paper, No. 120. Washington.

Plusquellec, H., C. Burt, and H.W. Wolter, 1994, *Modern water control in irrigation: Concepts, issues, and applications*, World Bank Technical Paper, No. 246, Irrigation and Drainage Series, Washington.

Postel, S. 1992, *The last oasis: Facing water scarcity*, Earthscan Publications, London.

Pradhan, T.M.S. 1996, *Gated or ungated water control in government-built irrigation systems: Comparative research in Nepal*, PhD thesis, Wageningen Agricultural University.

Prescott, W.H. and J.F. Kirk, 1887, *History of the conquest of Peru: With a preliminary view of the civilization of the Incas*, Rev. ed, Routledge, London.

Ramirez-Horton, S., 1974, *The sugar estates of the Lambayeque valley, 1670-1800: A contribution to Peruvian agrarian history*, University of Wisconsin.

Rap, E., P. Wester and L Nereida, forthcoming, "The politics of creating commitment: Irrigation reform and the reconstitution of the hydraulic bureaucracy in Mexico", accepted for publication in: P.P. Mollinga and A. Bolding (eds.) *The politics of irrigation reform.*

Reed, M.I., 1992, *The sociology of organizations: Themes, perspectives and prospects*, Studies in Sociology, Harvester Wheatsheaf, New York.

Repetto, R., 1986, *Skimming the water: Rent-seeking and the performance of public irrigation systems*, Research Report, nr 4, World Resources Institute.

Rhoades, J.D., A. Kandiah and A.M. Mashali, 1992, *The use of saline waters for crop production*, FAO Irrigation and Drainage Paper, No. 48, Rome, Italy.

Rischar, S., 1991, "El manejo social del agua en la costa peruana a través del tiempo", in: *Ruralter*, No. 9, CICDA, Lima, Peru, pp.211-234.

Rosegrant, M.W. and H.P. Binswanger, 1994, "Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation", in: *World Development*, Vol. 22, No. 11, pp. 1613-1625.

Sagardoy, J.A., 1996, "Sustainability concerns in the operation and maintenance of irrigation systems", in: L.S. Pereira, R.A. Feddes and J.R. Gilley (eds.), *Sustainability of irrigated agriculture, proceedings of the NATO advanced research workshop in Vimeiro, Portugal,* Kluwer Publishers, Dordrecht, The Netherlands.

Sanaee-Jahromi, S., H. Depeweg and J. Feyen, 2000, "Water delivery performance in the Doroodzan Irrigation Scheme, Iran", in: *Irrigation and Drainage Systems*, Vol. 14, pp. 207-222.

Sandweiss, D.H., 1995, "Cultural background and regional prehistory", in: T. Heyerdahl, and D.H. Sandweiss and A. Narvaez (eds.), *Pyramids of Túcume: The quest for Peru's forgotten city*, Thames and Hudson, London.

Sandweiss, D.H. and A. Narváez, 1995, "Túcume past", in: T. Heyerdahl, D.H. Sandweiss and A. Narvaez (eds.), *Pyramids of Tucume: The quest for Peru's forgotten city*, Thames and Hudson, London.

Scott, J.C., 1985, *Weapons of the weak: Everyday forms of peasant resistance*, Yale University Press, New Haven.

Seckler, D., 1996, *The new era of water resources management*, Research Report 1, International Irrigation Management Institute (IIMI), Colombo, Sri Lanka.

Sherbondy, J., 1994, "Water and power: The role of irrigation districts in the transition from Inca to Spanish Cuzco", in: W.P. Michell and D. Guillet (eds.), *Irrigation at high altitudes: The social organization of water control systems in the Andes*, Society for Latin American Anthropology publication series, Vol. 12.

Shiklomanov, I.A., 1999, *World water resources and water use: Present assessment and outlook for 2025*, State Hydrological Institute, St. Petersburg, Russia.

Sloan, G., 1997, "Evolution from manual canal control to remote canal control", in: *Proceedings of the International Workshop on Regulation of Irrigation Canals: State of the Art of Research and Applications*, April 1997, Marrakech, Morocco, pp.203-206.

Small, L.E. and I. Carruthers, 1991, *Farmer-financed irrigation: the economics of reform*, IIMI, Cambridge University Press.

Smith-Screen, P., 1995, *Accountability in development organizations: Experiences of women's organizations in India*, Sage Publications, New Delhi.

Southorn, N., 1997, *Farm irrigation: Planning and management*, INKATA Press, Australia.

Sutton, C.W., 1929, "La politica de irrigación del Perú", in: *Anales del Primer Congreso de Irrigación y Colonización del Norte*, 12-17 October 1928, 4 Volumes, Lima, Peru, pp. 1259-1273.

Svendsen, M., J. Trava, and S.H. Johnson III, 2000, "A synthesis of benefits and second-generation problems", in: D. Groenfeldt and M. Svendsen (eds.): *Case studies in participatory irrigation management*, World Bank Institute, Washington, Chapter 6.

Tang, S.Y. and E. Ostrom, 1993, *The governance and management of irrigation systems: An institutional perspective*, ODI Network Paper, No. 23, London.

Thobani, M. 1995, *Perú, enfoque de la ordenación del agua y el desarrollo de la irrigación basado en el usuario*, Informe No. 13642-PE, Oficina Regional para America Latina y el Caribe, World Bank.

Toledo, A., 1999, *Diagóstico de la legislación y las politicas de gestión del agua al nivel de las cuencas hidrográficas en el Perú*, unpublished report for SNV-Peru.

Trimborn, H., 1979, *El Reino de Lambayeque en el antiguo Peru*, Collectanea Instituti Anthropos, Vol. 19, n.p. Germany.

Tsur, Y. and A. Dinar, 1997, "The relative efficiency and implementation costs of alternative methods for pricing irrigation water", in: *The World Bank Economic Review*, Vol. 11, No. 2, pp. 243-62.

Tupac Yupanqui, V., 1929, "Administración del riego", in: *Anales del Primer Congreso de Irrigación y Colonización del Norte*, 12-17 October 1928, 4 Volumes, Lima, pp. 722-730.

Ugaz, F. and H. San Miguel, 1998, "La venta de arroz 'en hierba': Una modalidad de crédito informal", proceedings, *Sepia*, pp. 125-168, Lima, Peru.

Uphoff, N., 1986, *Improving international irrigation management with farmer participation: Getting the process right*, Studies in Water Policy and Management, No. 11, Westview Press, London.

Uphoff, N., 1992, *Learning from Gal Oya: Possibilities for participatory development and post-Newtonian social science*, Intermediate Technology Publications, London.

Uphoff, N., P. Ramamurthy and R. Steiner, 1991, *Managing irrigation: Analyzing and improving the performance of bureaucracies*, Sage, New Delhi.

Uphoff, N., M.I. Wickramasinghe and C.M. Wijayaratna, 1990, "'Optimum' participation in irrigation management: Issues and evidence from Sri Lanka", in: *Human Organization*, Vol. 49, No. 1, pp. 26-40.
Urban, K. 1990, *Grossbewasserungsanlagen in Peru*, PhD thesis (in German), Verlag Breitenbach Publishers, Saarbrucken, Germany.

Valdez, R., 1926, "Distribución de las aguas de regadío en nuestros valles costaneros, Necesidad de su reforma", in: *La Vida Agrícola*, Lima, Diciembre, pp. 1005-1016.

Vásquez, F. and R. Turkowsky, 2001, "Analisis de alternativas de uso de los grandes reservorios subterraneos de la costa del Peru", in: *Agua y Riego*, No. 16., pp.12-17, IPROGA, Lima, Peru.

Vermillion, D.L. and J.A. Sagardoy, 1999, *Transfer of irrigation management services, Guidelines*, Irrigation and Drainage Paper No. 58, IWMI, GTZ, FAO, Rome.

Villarreal, M., 1994, *Wielding and yielding: Power, subordination and gender identity in the context of a Mexican development project*, PhD thesis, Wageningen Agricultural University.

Vincent, L., 1997, "Agro-ecology, participation and irrigation: Learning from different system concepts", in: *More From Less: Better Water Management*, Workshop converted by DFID's Natural Resources Systems Programme (NRSP) 21-23 September 1997, pp.13-24, Cranfield University, Silsoe.

Vincent, L., 2001, "Struggles at the social interface: Developing sociotechnical research in irrigation and water management", in: P. Hebinck and G. Verschhor (eds.), *Resonances and dissonances in development: Actors, networks and cultural repertoires*, pp. 65-82, Van Gorcum, The Netherlands.

Waalenwijn, P., 2000, *Estudio de horas de pagado: Estudio realizado en el subsector de Ferreñafe en el valle Chancay-Lambayeque en el norte de Perú*, Report on practical period, Wageningen Agricultural University.

Wade, R., 1982, "The system of administrative and political corruption: Canal irrigation in South India", in: *Journal of Development Studies*, 1982, pp.287-328.

Wade, R., 1988, *Village Republic: Economic conditions for collective action in South India*, IDS, Cambridge.

Wade, R., 1990, "On the 'technical' causes of irrigation hoarding behaviour: Or why irrigators keep interfering in the main system", in: R.K. Sampath and R.A. Young (eds.): *Social, economic, and institutional issues in Third World Irrigation management*, Westview Press, Boulder.

Wahaj, R., 2001, *Farmers actions and improvements in irrigation performance below the Mogha: How farmers manage water scarcity and abundance in a large scale irrigation system in South-Eastern Punjab, Pakistan*, PhD thesis, Wageningen University.

Waller, T., 1994, "Expertise, elites, and resource management reform: Resisting agricultural water conservation in California's Imperial Valley", in: *Journal of Political Ecology*, Vol. 1, pp. 13-42.

Weber, M., 1947, *The theory of social and economic organization*, Routledge and Kegan Paul, London.

Winner, L., 1993, "Upon opening the black box and finding it empty: Social constructivism and the philosophy of technology", in: *Science, Technology & Human Values*, Vol. 18, No. 3, Summer, pp. 362-378.

Winpenny, J.T., 1994, *Managing water as an economic resource*, ODI, Routledge, London.

Wittfogel, K., 1957, *Oriental despotism: A comparative study of total power*, Yale University Press, New Haven.

Wolf, J.M., and J.E. Gleason and R.E. Hagan, 1996, "Conversion to drip irrigation: Water savings, fact or fallacy, lessons from the Jordan Valley", in: H.W. Greydanus and S.S. Anderson (eds.), *Irrigation Water Conservation, Opportunities and Limitations*, Procedings Water Management Seminar, 5-7 Oct. 1995, U.S. Committee on Irrigation and Drainage, Sacramento, California, pp.209-217.

World Bank, 1993, *Water resources management*, A World Bank Policy Paper, Washington.

World Bank, 1996, Irrigation Subsector Project, information can be found on: www4.worldbank.org/sprojects/ and on: www.psi.gob.pe

Yin, R.K. 1984, *Case study research: Design and methods*, Applied Social Research Methods Series, Vol. 5, Sage Publication, Newbury Park.

Zaag, P. van der., 1992, *Chicanery at the canal: Changing practice in irrigation management in Western Mexico*, PhD thesis, Wageningen Agricultural University.

Zegarra, J.M., 1978, "Irrigación y técnicas de riego en el Perú pre-colombino", in: R. Ravines (ed.), *Tecnologia Andina*, pp. 107-116.

Zavaleta, L.R., 1987, "Irrigation water policy effects on regional crop allocation in Peru", in: *Agricultural Systems*, No. 24, pp.249-268.

Zimbelman, D.D. (ed.), 1987, *Planning, operation, rehabilitation and automation of irrigation water delivery systems*, American Society of Civil Engineers, New York.

Zwarteveen, M.Z., 1997, "Water: from basic need to commodity: A discussion on gender and water rights in the context of irrigation", in: *World Development*, Vol. 25, No. 8, pp. 1355-1349.

Appendix I

Definitions regarding water allocation and scheduling

Introduction

It is important to separate water allocation from scheduling when defining different modes of assigning water to water users and/or their plots. This appendix first gives general definitions of water allocation and scheduling. Secondly, different principles of water allocation and different modes of water scheduling are presented. It must be stressed that there is still no consensus over the definitions given. Quite some attempts have been made to come to a universal classification of water distribution (e.g. Merriam 1992), but those provide some contradictions and unclear and overlapping definitions. The presented classification tries to improve the existing definitions.

Finally, an overview is given of the possible combinations of water allocation and scheduling (Table I.1). Examples of irrigation systems from different parts of the world are given to demonstrate how the classification works. However, the classification is not absolute; in most cases both allocation and scheduling are dynamic and flexible processes, and practices often are different from the official rules. Still the examples are useful to see the diversity of possibilities in the combinations between different modes of water allocation and scheduling.

Water allocation

Water allocation is the assignment of certain proportions of a certain flow or certain volumes of water to individuals or groups of water users. Water allocation forms part of the bundle of water rights. In the bundle of water rights the water use rights and obligations of the water users are defined.

Water allocation has three levels:

- First, the collective rights of a group to appropriate water from a source.
- Second, the regulations on who can get a water title and who not, what are the obligations to fulfil, and who has to authority to decide on that.
- Third, the regulations on how much water is assigned to each individual titleholder (or group of titleholders); when (during what period) this water is to be delivered; against what fees and obligations; and who decides on that.

Basically there are two options for the assignment of water (level three): share-based and volumetric based allocation. Both options can be subdivided according to the criteria used to allocate the water.

Share-based water allocation is the assignment of a certain proportion of an available flow to a titleholder, independent of the size of the available flow. For instance, in small-scale, farmer-managed irrigation systems in the Hills of Nepal individual plot owners have the right to use a certain proportion of the flow diverted from the river. The share can be based on the area of the plot relative to the complete command area. In other cases the share is based on investments made in the construction of the irrigation infrastructure. The farmers have created 'hydraulic property' by contributing to the building of the system (Coward 1986, Gerbrandy and Hoogendam 1996). The proportion of this contribution is translated to a proportion of the available water. Also contributions in maintenance are related to the share. In some exceptional cases shares are assigned on basis of special jobs: being ditch tender or guard.

Volumetric water allocation is the assignment of certain volumes of water to certain titleholders (individual or collective). In many cases a fee is levied related to the volume assigned. The idea behind volumetric allocation is that it enables a better match between crop water requirements and water supply. Volumetric water allocation can be either imposed or on request from the water users. In an imposed allocation a higher authority (normally a government agency) will calculate and determine the water to be allocated to farmers. In some cases the allocations are planned completely before the irrigation season and do not allow for any changes. It is recognised that in most systems this results in low productivity and low water use efficiency. Therefore, so-called 'real-time' allocation is introduced. In real-time allocation the water assignment is adapted during the irrigation season to the weather conditions, crop-stage and other relevant factors. Either fixed or real-time; this top-down approach is regarded as too rigid (or complicated if more flexible) to lead to good performance.

Therefore, nowadays, volumetric water allocation is associated much more with on-request water allocation. Farmers can request the amounts of water when their crops need it. This is supposed to lead to higher water use efficiencies and higher yields. To prevent over-use of water by the farmers (they might want to use it as a substitute for their labour input) the volumes of water to be requested are limited. Sometimes a volumetric fee is charged to conserve water, in other cases a maximum volume of water to be requested per irrigation season per hectare is established. These quotas are often crop-based.

Water scheduling

Water scheduling is defined as the set of operational rules that establish the frequency, time, duration, flow rate, and order among the water users, of the water delivery to the water users (and higher levels in the irrigation system).

Here four basic modes can be defined:

- Continuous flow: water is delivered to all parts in the system simultaneously in small but continuous flows.
- Free delivery (or on-demand): water users can take water whenever they want without need for prior notification to the irrigation agency. The irrigation infrastructure (canal or pipe) will set a maximum flow rate.
- Arranged scheduling: water turns are delivered to individual water users on basis of a schedule drawn up by the irrigation agency (or water users' association) one or more days in advance. This schedule can be decided upon by the higher authority or on request of the water users.
- Rotation: water is scheduled in water turns that follow the order of the water users along the tertiary canals. The time each water user has to irrigate can be fixed (and related to the area and crop) or flexible.

Table I.1: Overview of different combinations of allocation and scheduling principles (grey shaded areas represent combinations that are less likely to occur)

Water allocation →		**SHARES**		**SHARES**	**VOLUMES**			
				Translated to volumes	Imposed (based on crops, climate and soil)		On-request (with maximum flow rate)	
Scheduling ↓ (Water delivery on farm level)		Area proportional	Investment based	Allocation is area proport., each year translated to a volume	Crop based – season planning	Crop based – real-time	Flow rate is only restriction	With crop-based quota
Continuous flow		1	2		3			
Free delivery / on-demand							4, 5	
Arranged schedule				6, 7, 8	9	9'	10, 11	12, 13, 14, 17'
Rotation	Fixed	15,	16		17, 18, 19			
Rotation	Modified Duration	20, 21, 5'				22		

1. Indonesia, sawah system
2. Small-scale, farmer-managed irrigation systems in the Hills of Nepal in the wet season
3. Jequetepeque, Peru; rice areas in normal years (although the farmers can influence the flow to their fields and have crop based quota, thus could also be seen as 3')
4. Domestic water supply
5. Arequipa, Peru; 'Toma libre', in dry period: 5'
6. Alto Rio Lerma, Mexico (each year at start irrigation season the volume in the reservoir determines the volumes of water to be allocated to the secondary blocks on bases of their area)
7. Tehuacan Valley, Mexico (share-based, hours with constant flows are traded)
8. Guadalhorce, Spain
9. Gezira, Sudan; moving from 9 to 9'
10. Campo de Cartagena, Spain
11. MSIDD, Arizona, USA
12. El Operado, Mexico
13. Triffa, Morocco
14. Chancay-Lambayeque, Peru, in normal years
15. Warabandi, various large-scale irrigation systems in India and Pakistan: fixed duration per turn related to area, and fixed frequency
16. Small-scale, farmer-managed irrigation systems in the Hills of Nepal in the dry season
17. Riverland, Australia (e.g. Renmark), moved from 17 to 17'
18. Tungabhadra, India (allocation is fixed, related to the area of the secondary and tertiary blocks)
19. Jequetepeque and Chancay-Lambayeque, Peru: in water scarce periods
20. Tras-o-Montes, Portugal, '*Riego por terminado*', (each farmer can irrigate until the field is properly wetted, the turn will not return until other farmers have thus irrigated their fields)
21. Kottapalle, India (see 20)
22. System H, Mahaweli, Sri Lanka

References used for the cases in Table I.1:

2. Martin E.D. and R. Yoder, 1986, *Institutions for irrigation management in farmer-managed systems: examples from the Hills of Nepal,* IIMI Research paper, no. 5, Colombo, Sri Lanka.
3. This thesis
5. Holmes, R.C. 1986, *Irrigation in Southern Peru: The Chili Basin*, The University of Chicago, USA, Research Paper no. 212.
6. Kloezen, W.H. and Garces-Restrepo, *Assessing irrigation performance with comparative indicators: The case of Alto Rio Lerma irrigation district, Mexico*, IIMI Research Report No. 22, Colombo, Sri Lanka.
7. Enge, K.I. and S. Whiteford, 1989, *The keepers of water and earth: Mexican rural social organization and irrigation*, University of Texas Press, Austin, USA.
9. Plusquellec, H. 1990, *The Gezira irrigation scheme in Sudan: Objectives, design, and performance*, World Bank Technical Paper, No. 120. Washington.
10. Bentum, M. van, 1995, *Water, werk en waterwerken: De ontwikkeling van irriagatietechnologie in het stroomgebied van de Segura, Zuidoost-Spanje*, PhD thesis, Wageningen Agricultural University.
11. Clemmens, A.J., A.R. Dedrick, W. Clyme and R.E. Ware, 2000, "On-farm system performance in the Maricopa-Stanfield Irrigation and Drainage District area", in: *Irrigation and Drainage Systems*, No. 14, pp.93-120.
12. Zaag, P. van der. 1992, *Chicanery at the canal: Changing practice in irrigation management in Western Mexico*, PhD thesis, Wageningen Agricultural University, The Netherlands.
13. Hofwegen, van P.J.M. and H.M. Malano, 1997, "Hydraulic infrastructure under decentrilized and privatised irrigation system management", in: *DVWK Bulletin*, No. 20, pp. 188-216.
14. This thesis
15. Jurriëns, M. and F. Wester, 1995, "Warabandi revisited: To abandon or to improve a basically sound water delivery scheduling method?", in: *ILRI Annual Report 1995*, pp. 24-43, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.
16. Martin E.D. and R. Yoder, 1986, *Institutions for irrigation management in farmer-managed systems: examples from the Hills of Nepal,* IIMI Research paper, no. 5, Colombo, Sri Lanka.
17. Menzies, B.J. and P.N. Gray, 1983, *Irrigation and settlement in South Australian Riverland*, Department of Agriculture South Australia, Technical Paper No. 7.
18. Mollinga, P.P., 1998, *On the waterfront: Water distribution, technology and agrarian change in a South Indian canal irrigation system*, PhD thesis, Wageningen Agricultural University.
19. This thesis
20. Dries, A. van der, P. Hoogendam and J. Portela, 1996, "Effects of a technical intervention programme on the water distribution and water use", in: G. Diemer and F.P. Huibers (eds.), *Crops, people and irrigation: Water allocation practices of farmers and engineers*, IT Publications, London, pp. 116-127.
21. Wade, R. 1988, *Village Republics: Economic conditions for collective action in South India*, IDS, Cambridge.
22. Weerakkody, P., 1986, *Farmer–officer coordination to achieve flexible irrigation scheduling: A case from System H, Sri Lanka*, IIMI Case study No. 3., Colombo, Sri Lanka.

Other references used:

Coward, E.W., 19986, "Sate and locality in Asian irrigation development: The property factor", in: K.C. Nobe and R.K. Sampath (eds.), *Irrigation management in developing countries, Studies in water policy and management*, Westview Press, Boulder, pp. 491-508.

Gerbrandy, G. and P. Hoogendam, 1996, "The materialization of water rights: Hydraulic property in the extension and rehabilitation of two irrigation systems in Bolivia", in: G. Diemer and F.P. Huibers (eds.), *Crops, people and irrigation: Water allocation practices of farmers and engineers*, IT Publications, London, pp. 53-72.

Merriam, J.L., 1992, "The need on the farm for a flexible water supply schedule", in: Proceedings of an international conference, *Advances in planning, design and management of irrigation systems as related to sustainable land use*, Leuven, Belgium, 1992, pp. 147-156.

Appendix II

River discharges of the Chancay and Jequetepeque rivers (1960-2000)

Table II.1: Annual river discharges (Sources: Carpio and Mejia 1996, De Bruijn 1999, and *Juntas de Usuarios*)

Year	Chancay-Lambayeque (in million m^3)	Jequetepeque (in million m^3)
60-61	664	534
61-62	853	314
62-63	396	556
63-64	797	746
64-65	855	793
65-66	700	493
66-67	858	1,932
67-68	395	185
68-69	892	540
69-70	968	527
70-71	1,578	1,192
71-72	1,288	997
72-73	1,070	1,193
73-74	1,111	901
74-75	1,718	1,981
75-76	1,179	848
76-77	933	855
77-78	614	264
78-79	811	602
79-80	375	88
80-81	919	915
81-82	772	425
82-83	1,659	2,075
83-84	1,390	1,561
84-85	609	346
85-86	892	476
86-87	985	541
87-88	894	523
88-89	1,338	1,139
89-90	665	292
90-91	944	442
91-92	628	317
92-93	1,254	1,059
93-94	1,382	1,446
94-95	700	490
95-96	1,207	949
96-97	584	254
97-98	2,122	2,629*
98-99	1,283	1,360*
99-2000	1,130	nd
Average	985	841
Sd	381	582
Maximum	2,122	2,629
Minimum	375	88
75% chance of exceedance	689	442

For Chancay-Lambayeque the hydrological year runs from August to July, discharges include the extra water from the tunnels
For Jequetepeque the hydrological year runs from October to September
* from January to December

Appendix III

Production costs and benefits of maize, rice and sugarcane

The average production costs per hectare are estimated for an 'optimal' and a 'minimal' production strategy. The 'optimal' strategy uses all the inputs and executes all required control measures as recommended by the local extension stations. The 'minimal' production strategy is what was found to be the treatment of the resource poor farmers. They use less labour and inputs, and have consequently lower yields. Two important remarks have to be made: first, many rice farmers were found to follow the 'optimal' production strategy, whereas for maize and sugarcane mostly the 'minimal' strategy was followed. Second, all data are averages and estimates, as labour and input needs differ per plot and prices fluctuate.

Maize (1 ha.)

Activity/input	Unity	Price per unity (US$)	Number used in 'optimal' treatment	Costs in 'optimal' treatment (US$)	Number used in 'minimal' treatment	Costs in 'minimal' treatment (US$)
Land preparation						
- clearing and burning	Labour day	3	3	9	3	9
- ploughing and harrowing	Hour machine	18	7	126	7	126
- borders	Labour day	3	2	6	2	6
- canal cleaning	Labour day	3	3	9	3	9
- first irrigation	Labour day	3	2	6	2	6
				Tot. 156		Tot. 156
Seeding						
- seeding	Labour day	3	10	30	10	30
- fertilising	Labour day	3	4	12	4	12
				Tot. 42		Tot. 42
Control measures						
- irrigation	Labour day	3.6	6	22	3	11
- application of agrochemicals	Labour day	3.6	6	22	1	4
- weeding	Labour day	3.6	4	14	2	7
- fertilising	Labour day	3.6	12	43	5	18
				Tot. 101		Tot. 40
Yielding						
- cutting	Labour day	3.6	8	29	6	22
- carrying	Labour day	3.6	6	22	4	14
- 'Despanque'	Labour day	3.6	10	36	5	18
- trashing machine	Sack (100kg)	0.75	50	38	25	19
				Tot. 125		Tot. 73
Inputs						
- seed	Kg	0.85	25	21	25	21
- Urea	Sack of 50 kg	10	8	80	4	40
- Phosphate	Sack of 50 kg	8.5	4	34	1	9
- Irrigation water	500 m3	3.3	10	33	5	17
- Pesticides				33		0
- Transport				14		10
				Tot. 215		Tot. 97
Direct cost				639		408
Credit (2.5%/month)				121		76
Total costs				760		486
Yield (kg maize grains)				5000		2500
Farm gate price per kg				0.2		0.2
Net benefit				240		14

*Maize for animal fodder

Rice (1 ha. including seedbed)

Activity/input	Unity	Price per unity (US$)	Number used in 'optimal' treatment	Costs in 'optimal' treatment (US$)	Number used in 'minimal' treatment	Costs in 'minimal' treatment (US$)
Land preparation						
- Clearing and *burning*	Labour day	3	4	12	4	12
- Weeding	Labour day	3	4	12	4	12
- Ploughing	Hour machine	18	3	54	3	54
- Levelling	Hour machine	18	1	18	1	18
- Borders	Labour day	3	4	12	4	12
- Canal cleaning	Labour day	3	4	12	4	12
- First irrigation	Labour day	3	3	9	3	9
				Tot. 129		Tot. 129
Seed bed						
- Borders	Labour day	3	2	6	2	6
- Ploughing	Oxen plough	12	0.5	6	0.5	6
- First irrigation	Labour day	3	1	3	1	3
- Levelling	Oxen plough	12	0.5	6	0.5	6
- Seeding	Labour day	3	0.5	1.5	0.5	1.5
- Fertilising	Labour day	3	0.5	1.5	0.5	1.5
- Weeding	Labour day	3	2	6	2	6
- Irrigation	Labour day	3	0.5	1.5	0.5	1.5
				Tot. 32		Tot. 32
Transplanting						
- wet levelling	Labour day	3.6	4	14	4	14
- sacking of seedlings	Labour day	4.2	9	38	9	38
- carrying of seedlings	Labour day	3.6	3	11	3	11
- transplanting	Labour day	3.6	20	72	20	72
				Tot. 135		Tot. 135
Control measures						
- irrigation	Labour day	3	5	15	3	9
- application of agro-chemicals	Labour day	3.6	1.5	5	0.5	2
- weeding	Labour day	3.6	30	108	15	54
- fertilising	Lab our day	3.6	3	11	2	7
- guarding of yield	Labour day	3	6	18	6	18
				Tot. 157		Tot. 90
Yielding						
- cutting	Labour day	3.6	11	40	6	22
- carrying	Labour day	3.6	11	40	6	22
- making of heap	Labour day	3.6	1	4	0.5	2
- 'recojo'	Labour day	3.6	2	7	1	4
- trashing machine	Sack (100kg)	1.4	100	140	50	70
				Tot. 231		Tot. 120
Inputs						
- seed	Kg	0.45	120	54	120	54
- Urea	Sack of 50 kg	10	13	130	5	50
- Ammonium sulphate	Sack of 50 kg	7.6	3	23	0	0
- Irrigation water	500 m3	3.3	14	46	7	23
- Herbicides	Sack of 25 kg	25.8	1	26	1	26
- Fungicides	Bottle	24	1	24	0	0
- Insecticides	Bottle	9	1	9	0	0
- Hormones	Sack	4.5	1	5	0	0
- Transport	-	3	1	3	0	0
				Tot. 320		Tot. 153
Direct cost				1004		659
Credit (2.5%/month)				191		125
Total costs				1195		784
Yield (kg polished rice)				7000		3500
Farm gate price per kg				0.24		0.24
Net benefit				485		56

Sugarcane (1 ha. including installation)

Activity/input	Unity	Price per unity (US$)	Number used in 'optimal' treatment	Costs in 'optimal' treatment (US$)	Number used in 'minimal' treatment	Costs in 'mininal' treatment (US$)**
Land preparation for installation*						
- Clearing and burning	Labour day	3	6	18	6	18
- Subsoiling	Hour machine	18	4	72	4	72
- Ploughing and harrowing	Hour machine	18	6	108	6	108
- Levelling	Hour machine	18	4	72	4	72
- Borders	Labour day	3	4	12	4	12
- making of furrows	Hour machine	18	3	54	3	54
- canal cleaning	Hour machine	18	2	36	2	36
- first irrigation	Labour day	3	3	9	3	9
				Tot. 381/6=64		Tot. 381/8=48
Installation*						
- seeding	Labour day	3	16	48	16	48
- reseeding	Labour day	3	1	3	1	3
- seedlings	number	3	65 Tm	195	65 Tm	195
				Tot. 246/6=41		Tot. 246/8=31
Land preparation						
- clearing and burning	Labour day	3	6	18	6	18
- canal cleaning	Hour machine	18	2	36	2	36
- borders	Labour day	3	3	9	3	9
- repair of furrows	Hour machine	18	1	18	1	18
- irrigation	Labour day	3	5	15	5	15
				Tot. 96		Tot. 96
Control measures						
- irrigation	Labour day	3	20	60	14	42
- application of agro-chemicals	Labour day	3	12	36	4	12
- weeding	Labour day	3	13	39	8	24
- fertilising	Labour day	3	5	15	2	15
				Tot. 150		Tot. 93
Yielding						
- cutting and burning	Labour day	3	42	126	22	66
	Hour machine	18	18	324	9	162
- carrying				Tot. 450		Tot. 228
Inputs						
- Urea	Sack of 50 kg	10	15	150	4	40
- Phosphate	Sack of 50 kg	8.5	2	17	0	0
- Dung	50 kg	0.4	40	16	40	16
- Irrigation water	500 m3	3.3	30	99	20	66
- Herbicides	Sack of 25 kg	25.8	6	155	2	52
- Biological Control				300		100
- Transport				100		50
				Tot. 837		Tot. 324
Direct cost				1638		820
Credit (45%/year)				737		369
Total costs				2375		1189
Yield (kg sugarcane)				200,000		80000
Yield (kg refined sugar)				(10%) 20,000		8000
Farm gate sugar price (per kg)				0.2		0.2
Net benefit				1625		411

*Each six years the sugarcane is uprooted and planted again. The five ensuing years the sugarcane is burned and cut.

** low investment: 8-years cycle

Appendix IV

Water delivery performance of intake to the Sialupe-Sodecape tertiary canal (Muy Finca)

In Figure IV.1 the programmed and measured flows to the secondary canal Sialupe-Sodecape in Subsector Muy Finca from February 1 to May 24, 1999 are presented. Intake flow was measured with a permanent Parshall flume (6 feet throat width) each morning. It must be noted that this canal actually serves two tertiary blocks: Sialupe-Sodecape and Aujeriada. The number of *mitas* programmed change almost daily (one *mita* is 190 l/s at the intake of the tertiary to be able to deliver *riegos* of 160 l/s at field level). Clearly water demands are highest in the first weeks of February (up to 10 *mitas* are programmed).

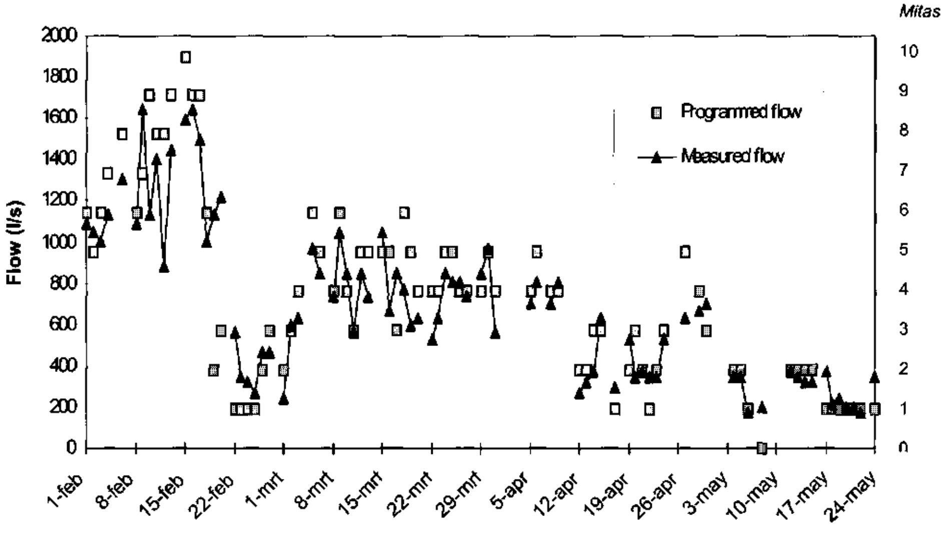


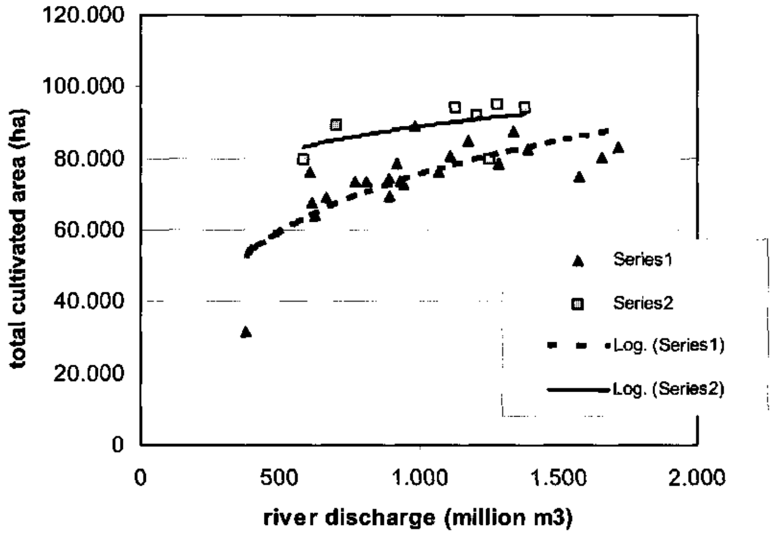
Figure IV.1: Programmed and measured flows to the tertiary canal Sialupe-Sodecape from February 1 to May 24, 1999 (Source: official distribution schedule and own readings of the Parshall flume)

The average Delivery Performance Ratio (DPR) is 1.06 and the sd is 0.44. Thus, the average delivery to the tertiary canal is quite good (DPR very close to 1.0), however, the sd is quite high indicating that on some days much more water is delivered than programmed and on other days much less water is delivered than programmed. This can most probably be contributed to the fact that Muy Finca is a tail-end Subsector. However, also the skills and motivation of the *sectorista* and *tomero* should be considered. The effects of the tail-end position and the human factor cannot be separated easily. However, because the intake is a undershot gate and the ongoing canal (called Heredia) also has undershot gates, the big deviations like distributing 347 l/s, while 190 l/s is programmed (April 22) are likely to be intentional deviations.

Appendix V

Effect of volumetric water charging on the total cultivated area in Chancay-Lambayeque

After 1992 the farmers paid their water turns according to the volume requested. To assess the effect of charging per volume the total cultivated areas from 1970 to 1991 were compared with the total cultivated areas in the years 1992 to 2000. Figure V.1 shows the relation of the total cultivated areas (for the two series) with the river discharge. As can be seen the area increases for both series with more river supply. However, the in the years 1992 to 2000 the average total cultivated area is some ten to twenty percent higher than the averages for the 1970-1992 years. This could partially be the effect of volumetric charging. As farmers are forced to apply less water, a bigger area can be cultivated. However, if this were the only cause of the difference between the series it would be expected that the effect of water saving (and thus bigger area) would be more with bigger river discharges. As can be seen in the figure, this was not found. Thus, other causes might have affected the cultivated area, like: reservoir management, reduced sugarcane production, and better monitoring of the maximum allowed volumes per year per hectare.



Series 1: Irrigation seasons 1970-71 to 1990-91
Series 2: Irrigation seasons 1991-92 to 1999-00 (not including El Niño season 1997-98)

Figure V.1: Effect of charging per volume on the total cultivated area in Chancay-Lambayeque

SUMMARY

This thesis describes the organisation and performance of two large-scale irrigation systems in the North Coast of Peru. Good water management is important in this area because water is scarce and irrigated agriculture provides a livelihood to many small and middle-sized farmers. Water in the coast of Peru is considered to be badly managed, however this study shows that performance is more optimal than critics assume. Apart from the relevance in the local water management discussion, the study also addresses two internationally much debated topics in irrigation water management: irrigation management transfer (from government to water users' associations) and modernisation of infrastructure.

Large-scale irrigation is often associated with low water use efficiencies, low control over the deliveries and low fee-recovery. Volumetric water control is one of the solutions proposed to solve these problems. The idea behind volumetric water control is to allocate and schedule precise volumes of water to meet crop water requirements, if possible on request of the water users. The user is charged per volume of water used to prevent over-use, and to raise sufficient funds to operate and maintain the irrigation system. Many authors stress the difficulties of volumetric water control. For example: on-request scheduling is too costly in large systems with many smallholders. High-tech automatic water control systems are too expensive and difficult to operate and maintain. Setting of the Irrigation Service Fee (ISF) might be too low to provide an incentive for water saving, or might be too high for poor farmers to pay.

The study aims to achieve a better understanding of the practices in organisation and performance of volumetric water control in two large-scale irrigation systems in the North Coast. The coastal zone of Peru is extremely arid. Precipitation is near zero, except once in about 15 years when the El Niño phenomenon brings heavy rains and floods. The irrigation systems depend on the highly irregular rivers, which flow from the Andean Mountains. Main crops in the coastal areas are: sugarcane, rice and maize. Two systems were selected for a comparative study: Chancay-Lambayeque (100,000 ha) and Jequetepeque (40,000 ha). In the Chancay-Lambayeque system the users pay US$ 2 per 576 m^3 scheduled to be delivered at field level. In the Jequetepeque system the farmers pay a fixed fee according to the crop allowed to grow. For example they pay US$ 60 per hectare of rice.

The analytical framework highlights two main points: First, the irrigation infrastructure has certain properties, because different stakeholders designed and constructed parts of it in the past. These properties set certain requirements for use. For example the manually operated, undershot gates need skilled and experienced personnel to operate them well. The properties of the infrastructure also affect the water distribution in particular ways. For example a system with undershot offtakes and no check structures in the ongoing canal transports all fluctuations in the inflow to the tail-end of the canals. This affects the farmers in these areas. Second, the organisations can be regarded as 'semi-autonomous fields' where rules and regulations are transformed and local regulations are applied. Social power relations, technical properties, environmental conditions and the interests of actors influence the rules that are used, how and when. The different organisations that manage the irrigation system form a complex entity. At different levels in the system; water users' organisations, private companies and government agencies play a role in water management. This complex entity can be studied by looking at the domains of authority the organisations have, the rules they use, and the structure of decision-making and accountability between the organisations.

Conflicts can reveal the rules used and the power plays involved. During one and a half year field research many key informants and water users were interviewed and a water flow measurement programme was executed.

Chapter 2 describes the setting of the two irrigation systems: the natural resources, the long history of irrigation in the area and the present production systems. As the coast is arid and plain, waterlogging and salinity are dangers of irrigation. Irrigation began already 3000 years ago. The present main canal of the Chancay-Lambayeque system was built around AD 1000 and the irrigated area then was larger than today. After the conquest the Spaniards largely continued the management of the Incas. Only when the new settlers claimed increasingly more land for their *haciendas,* conflicts about water grew. State interventions in the management of the systems started early 20th century. At that time the idea of volumetric water control was proposed. However, it was not until the Agrarian Reform of 1969, when the management became completely in the hands of the State, that volumetric allocation and delivery was introduced. And only with the Irrigation Management Transfer (IMT) to the *Comisiones de Regantes* and *Juntas de Usuarios* in 1992 volumetric charging was enforced. Today sugarcane and rice are cultivated in high input – high output production systems. Main problem for the small and middle-sized landowners is to obtain credit. The local rice purchasers (*molinos*) provide credit, which leads often to ever greater indebtedness of the smallholders. Execpt for the three sugarcane co-operatives the average landholding is 5 ha.

Chapter 3 introduces the complex structure of the entities that manage the irrigation systems. Since the Irrigation Management Transfer in 1992 the *Comisiones de Regantes* (CRs) at the level of the secondary canals operate and maintain the secondary canals. The board of the *Comisiones* is elected by all water users. For the operation the board hires staff. At the level of the tertiary canals the *Comités de Canal* maintain (and sometimes operate) the tertiary canals. In 1994 (for Chancay-Lambayeque) and 1998 (for Jequetepeque) the *Juntas de Usuarios* formed private companies to take over the operation and maintenance of the main canal and reservoirs. The local irrigation offices of the Ministry of Agriculture (ATDR) retained the authority to allocate water (up to the individual plot level) and supervise the management by the water users' organisation. Besides the ATDR also the Autonomous Watershed Authorities (AACH) and the Special Project Bureaus are government organisations that have certain domains of authority in water management.

The main difference in water use between the systems is that the water users in Jequetepeque apply on average twice as much water per hectare of the same crop compared to the users in Chancay-Lambayeque. This is not caused by the volumetric payment in Chancay, but by the difference in water availability per hectare. After the Land Reform the Chancay system was expanded to win political support with the new water users, whereas in Jequetepeque the luxurious water right position acquired by the *haciendas* was not changed.

Chapter 4 describes the practices of volumetric water allocation and scheduling. The National Water Law of 1969 establishes that all water is property of the State and that the ATDR is the organisation that gives concessions for use to individual water users. The ATDR also establishes how much water each user can request maximum depending on the defined cropping zones. However, for the scheduling of water turns according to the cropping plan the ATDR depends on the *Comisiones de Regantes*. The *Comisiones*, however, generally comply with the cropping plan to avoid claims of water users for water they are entitled to. Apart from the permanent water rights (*licencia*) there are also water titles for excess water (*permiso*). This institution was already known in the pre-Inca times. It is an adaptation to the ever fluctuating river supplies. In Chancay-Lambayeque water is scheduled in '*riegos*'. One *riego* is one hour of water delivery with 160 l/s at field level. The water users pay in advance and get the hours the next day. In Jequetepeque the turns are only scheduled at the beginning of the rice-growing season. During the remainder of the rice-growing season the water flows continuously from field to field.

In water scarce periods, when supply is less than expected, the *Junta de Usuarios* together with the ATDR adjust the water allocations. In Chancay-Lambayeque all water users then get scheduled a fixed number of hours each 15 days. The number of *riegos* per hectare is proportionally less the bigger the landholding of the farmer. This results in plots only party planted with rice, but more often in plots completely planted, but deficiently irrigated. In Jequetepeque water scarcity comes less unexpected, because the reservoir has sufficient capacity for an irrigation season. Here certain *campos* (small clusters of fields) are excluded from rice growing when the reservoir is low.

In Chapter 5 an assessment is made of the volumetric water delivery. First a framework for understanding delivery performance is given. In this framework three main factors are central: the physical infrastructure, the operators, and the water users. However, in the first place the Relative Water Supply (RWS) should be looked at. The RWS is the ratio of the delivered water and the crop water requirements. If the RWS at field level is higher than 1.5 water can be used as a substitute for control. An intensive water flow measurement programme was executed to assess the performance of the water delivery service. Water flows were measured at all levels of the canal system: from offtakes from the main canal to deliveries at field level. The Chancay-Lambayeque system with its manually operated undershot gates, few measurement structures, open and unlined canals, its irregular river supply, and complicated on-request scheduling for 22,000 water users is a 'nightmare' system. Nevertheless, the Delivery Performance Ratio (DPR) was remarkably close to 1.0 at different levels of the system, indicating that the actually delivered flows were as programmed. This together with a RWS of between 0.6 and 0.8 at field level leads to a high water productivity. The remarkably good water delivery performance was explained by the skills of the operators and the accountability of the boards of the *Comisiones* towards the water users. This accountability was a result of the board members wanting to win the next elections to remain in the position to make money from illegal water selling. Also radio and newspapers were used to exert pressure on the boards to perform well. In Jequetepeque the DPR was almost always above 1.0 indicating that there was more water distributed than programmed. This was explained by the fact the in Jequetepeque the RWS was about 2.

Chapter 6 focuses on the financial conduct of the two irrigation systems. The charge for the water delivery service is set by the General Assemblies of the water users. They prioritise the expenditures of the *Comisiones* and therewith set the fee. The fees are recovered by the *Junta de Usuarios* (or its private company) and then distributed over the different organisations that manage the systems. The fee recovery was high. In Chancay-Lambayeque from 1993 to 1998 more than ninety percent of the distributed water was paid for (per volume). Users paid per *riego*, thus recovery was spread throughout the irrigation season. The advance payment could be enforced quite well because of social and technical control over the water. Only the sugarcane co-operatives in the head-end of the system took water without paying. A drawback of volumetric charging is that less river supply means less income for the organisations. Also in Jequetepeque the fee recovery was high. Here the farmers did not pay per volume and the recovery was harder to enforce because of abundant water availability. Therefore, the *Junta* collected the fees at the beginning of the irrigation season when the system was still dry but the rice farmers need to start their nurseries. By strict control over the water to only those users who had paid the fees of last year the *Junta* recovered the fees. The farmers could not wait with their nurseries until water would be available abundantly because a later start would mean a yield reduction due to low temperatures at the end of the season. This construction of technical, environmental and institutional elements that enforces the payment was called an 'obligatory point of passage'.

Between 1.5 to 3.0 million dollars were collected each year in each system. This was more or less sufficient for operation and maintenance and paying taxes. The distribution of the funds was such that the *Comisiones* had insufficient budget for maintenance, however, the maintenance of the tertiary canals was done by the *Comités de Canal*, and some subsidies became available from the 1998 El Niño floods.

Chapter 7 evaluates the functioning and effects of volumetric water allocation, scheduling, delivery and charging. It is concluded that water control in Chancay-Lambayeque is volumetric. In Jequetepeque water allocation and distribution is only volumetric to a certain extent, and charging is not related to the volume actually applied to the field. In both systems there are two important factors shaping water management. First, the history of the institutions and physical infrastructure. Despite the many abrupt changes in the institutional setting the continuities in the long history contributed to the legitimacy of the rules and the functionality of the infrastructure. Second, the contemporary institutions bring about a power balance among the various organisations involved in irrigation management. The governance of the organisation follows surprisingly strictly the National Water Law. Only some minor rules are not complied with. Rule-compliance is partly enforced by social control among 'equal' parties: e.g. farmers in the tertiary block guard their water against theft, and engineers of the *Comisiones* ensure they get allocated water for their Subsector according to the rules. Rules are also enforced by the governmental organisations ATDR and AACH. They judge about certain types of conflicts (on rule violation) inside the users' organisations. Punishment of rule violation is also used in political ways: a fine by the ATDR implies exclusion of the involved water user from the next election of the board of the *Comisión*.

The effect of volumetric water control on productivity of water is small. It is much more the water availability per hectare that determines the productivity of water. The water in Chancay-Lambayeque is 'stretched' over a much bigger area compared with Jequeteque making water more productive per volume of water applied. The volumetric charging affected livelihoods of poor farmers because it was difficult for them to find the money to pay the water turns when the crops required water. However, as the production system is high input – high output, the farmers invest much money anyway and the water fee is only 5 to 10 percent of the total input costs. The payment per volume made the board and staff of the *Comisiones* somewhat more accountable in water delivery to the water users.

It is concluded in Chapter 8 that the power balance between the water users, different water users' organisations, private company and different public agencies shaped a well functioning entity. The general governance regulations were complied with, but locally rules on allocation, scheduling, maintenance and fee setting were refined and negotiated. It was also concluded that the analytical framework and research methods used in the comparative study were useful in revealing the complex nature of the irrigation management.

DUTCH SUMMARY

Metrische zaken (doen er toe): De resultaten en organisatie van volumetrisch waterbeheer in grootschalige irrigatie in de noordkust van Peru

Dit proefschrift beschrijft de organisatie van twee grootschalige irrigatiesystemen aan de noordkust van Peru. Grootschalige irrigatie wordt vaak geassocieerd met lage watergebruiksefficiënties, slechte controle over de waterdistributie en slechte financiële prestaties. Volumetrisch waterbeheer is één van de oplossingen die worden voorgesteld om deze problemen op te lossen. Het idee achter volumetrische waterbeheer is om precieze volumes van water toe te wijzen (op aanvraag van de boer) die de waterbehoefte van de gewassen dekt. De gebruiker betaalt per gebruikt volume om over-gebruik te voorkomen en om over voldoende financiële middelen te beschikken voor het gebruik en onderhoud van het irrigatiesysteem. De exacte volumes dienen op precies het goede tijdstip en op precies de goede plaats geleverd te worden. Daarom kunnen we stellen dat volumetrische watercontrole drie dimensies heeft: volumetrische water toekenning, volumetrische water aflevering, en volumetrische betaling. Veel auteurs benadrukken de moeilijkheden van volumetrisch water beheer. Bijvoorbeeld: volumetrische levering aan kleine boeren in een groot systeem zou te duur zijn. Hightech automatische water controle technologieën zouden te duur zijn en te moeilijk zijn in gebruik en onderhoud. De vaststelling van de waterheffing zou te laag kunnen zijn om een prikkel te geven voor water besparing of zou te hoog kunnen zijn voor arme boeren.

De studie heeft als doel te komen tot een beter begrip van organisatie en prestatie in de praktijk van volumetrisch waterbeheer in twee grootschalige irrigatiesystemen aan de noordkust van Peru. De kust van Peru is extreem droog. Neerslag is bijna nul, behalve tijdens de El Niño regens en overstromingen die eens in de 15 jaar optreden. De irrigatiesystemen verkrijgen hun water uit rivieren die uit de Andes stromen met heel onregelmatige afvoer. De belangrijkste gewassen in de kust zijn: suikerriet, rijst en maïs. Twee systemen werden uitgekozen voor een vergelijkende studie: Chancay-Lambayeque en Jequetepeque. In het 100.000 ha grootte Chancay-Lambayeque systeem betalen de gebruikers 2 dollar voor aflevering van 576 m3 water op veldniveau. In het 40.000 ha grootte Jequetepeque betalen de gebruikers een vaste heffing per hectare afhankelijk van het gewas waarvoor toestemming is verkregen. Bijvoorbeeld 60 dollar voor een hectare rijst. De redenen voor deze verschillende wijze van betaling en de effecten daarvan werden bestudeerd.

Verschillende concepten worden gepresenteerd die gezamenlijk een analytisch kader vormen om irrigatie beheer te bestuderen. Op de eerste plaats worden irrigatiesystemen gedefinieerd als sociaaltechnisch entiteiten, waar water, infrastructuur, water gebruikers, hun organisatie en overheidsinstanties de belangrijkste elementen vormen. Water wordt toegekend aan gebruikers volgens bepaalde principes: 'eigendomsregimes' en waterrechten. Irrigatiewater wordt gecontroleerd door de infrastructuur. De mate van controle die nodig is hangt af van het type kanalen (open of pijpleidingen) en verdeelwerken (vast of te reguleren). De relatieve water voorziening (schaarste of overschot) beïnvloedt het beheer van de infrastructuur. Extra water kan dienen als een substituut voor controle. Bepaalde belanghebbenden beïnvloeden het ontwerp en de constructie van irrigatie infrastructuur. Die infrastructuur heeft daarom bepaalde voorwaarden voor gebruik. Bijvoorbeeld: handmatig te bedienen verdeelwerken

vereisen een goed geschoolde en ervaren bediener. De specifieke eigenschappen van de infrastructuur hebben ook specifieke effecten op de waterverdeling. Bijvoorbeeld een systeem met 'undershot' verdeelwerken en zonder regulatiewerken in de doorgaande kanalen transporteert de fluctuaties in de debieten naar het einde van de kanalen. Dit benadeelt de boeren in deze gebieden.

De verschillende organisaties die het irrigatiesysteem beheren vormen samen een complexe entiteit. Watergebruikers-organisaties, privé-bedrijven en overheidsinstanties spelen een rol in het waterbeheer op verschillende niveaus in het systeem. Deze complexe entiteit kan bestudeerd worden door te kijken naar de 'domeinen van autoriteit' die de verschillende organisaties hebben, de regels die zij gebruiken, en de structuren van besluitvorming en verantwoording tussen de verschillende organisaties. Macht speelt een belangrijke rol in de interacties in, en tussen, de organisaties. Conflicten brengen de regels die gebruikt worden en de machtsrelaties aan het licht. Gedurende anderhalf jaar veldonderzoek werden velen sleutelinformanten en watergebruikers geïnterviewd. Tevens werd er een intens debiet meetprogramma uitgevoerd om de waterdistributie te evalueren. Er werden debieten gemeten op alle relevante niveaus in de systemen: van hoofdsysteem tot veldniveau.

In hoofdstuk 2 wordt de context van de twee systemen geschetst: de natuurlijke hulpbronnen, de lange geschiedenis van irrigatie in de gebieden, en de huidige productie systemen. Omdat de kust droog en vlak is kan irrigatie verzouting en een te hoge grondwaterstand veroorzaken. De grote fluctuaties in de rivierafvoer, tussen jaren en gedurende het irrigatie seizoen, bemoeilijken het waterbeheer. Irrigatie werd reeds 3000 jaar geleden ontwikkeld en het huidige hoofdkanaal van Chancay-Lambayeque werd 1000 jaar geleden aangelegd. Rond die tijd was het geïrrigeerde areaal groter dan het huidige areaal. Na de verovering door de Spanjaarden werd het waterbeheer van de Inca's voortgezet. Pas toen de *haciendas* steeds meer land opeisten groeiden de conflicten. Overheidsbemoeienis begon in het begin van de 20ste eeuw. Toen werd het idee van volumetrisch waterbeheer geïntroduceerd. Echter, de overheid kon volumetrische watertoekenning en distributie pas toepassen nadat zij het waterbeheer in zijn geheel had overgenomen na de Land Hervorming in 1969. Volumetrische betaling werd pas ingevoerd na de overdracht van het beheer van de systemen van de overheid door *Comisiones de Regantes* en *Junta de Usuarios* in 1992. Suikerriet en rijst worden tegenwoordig geproduceerd in een systeem dat gekenmerkt wordt door hoge input en hoge opbrengsten. Krediet is voor de kleine en middel grote boeren het grootste probleem. De locale rijstopkopers (*molinos*) leveren kredieten die leiden tot steeds groter wordende schulden van de boeren.

Hoofdstuk 3 beschrijft de complexe structuur van de entiteiten die de irrigatiesystemen beheren. Sinds de overdracht in 1992 beheren de *Comisiones de Regantes* de kanalen op secondair niveau. Deze watergebruikers-organisaties distribueren het water en onderhouden de infrastructuur. Het bestuur van de *Comisiones de Regantes* wordt gekozen door de watergebruikers. Het bestuur neemt personeel aan voor het dagelijks beheer. Op het niveau van tertiaire vakken onderhouden de *Comités de Canal* de kanalen, en soms distribueren ze het water. *Juntas de Usuarios* zijn overkoepelende organisaties op hoofdsysteemniveau. De *Juntas de Usuarios* formeerden (in 1994 voor Chancay-Lambayeque en in 1998 voor Jequetepeque) privé-bedrijven voor het beheren van de hoofdinfrastructuur: hoofdkanaal, reservoir en hoofdinlaatwerken. Het lokale irrigatiekantoor van het Ministerie van Landbouw (ATDR) behield de autoriteit om water toe te wijzen (op veldniveau) en het beheer van de verschillende watergebruikers-organisaties te controleren. Naast de ATDR zijn ook de

Autonome Stroomgebiedinstantie (AACH) en de Speciale Project Bureaus overheidsorganisaties die bepaalde bevoegdheden hebben in het waterbeheer.

Het watergebruik per hectare voor dezelfde gewassen was in Jequetepeque twee maal zo hoog in vergelijking met Chancay-Lambayeque. Dit werd echter niet veroorzaakt door de volumetrische betaling in Chancay-Lambayeque, maar door de lagere waterbeschikbaarheid in Chancay-Lambayeque. Na de Land Hervorming werd het Chancay-Lambayeque systeem uitgebreid in ruil voor politieke steun. Terwijl het Jequetepeque systeem haar luxueuze water rechten uit de *hacienda*-tijd kon behouden.

Hoofdstuk 4 beschrijft de toewijzing van waterrechten en de vaststelling van de waterbeurten. De Nationale Waterwet van 1969 stelt dat alle water eigendom is van de Staat. De ATDR geeft de gebruiksconcessies uit aan individuele gebruikers. Dit gebeurde op basis van bestaand recht. De ATDR bepaalt ook hoeveel water elke gebruiker maximaal mag aanvragen afhankelijk van de ingestelde gewaszone. De ATDR is afhankelijk van de *Comisiones de Regantes* voor de uitvoering van de regels. De *Comisiones* gebruiken de officiële regels omdat ze claims van watergebruikers willen vermijden die aanspraak maken op de officiële watertoedeling. Er bestaan twee soorten waterrechten: *licencia* en *permiso*. *Licencia* is een permanent waterrecht. *Permiso* is een recht op water bij een eventueel overschot in de rivier. Dit verschil bestond al in the Inca-tijd, en is een reactie op de sterk fluctuerende rivierafvoeren. In Chancay-Lambayeque wordt water gedistribueerd in '*riegos*'. Een *riego* is een uur water levering met 160 l/s op veldniveau. Bij voldoende water kunnen de boeren zoveel water kopen als ze willen. Ze betalen de dag van tevoren. In Jequetepeque worden individuele beurten alleen in het begin van het rijstgroeiseizoen geprogrammeerd. Gedurende de rest van het rijstgroeiseizoen stroomt het water continue van veld naar veld.

In waterschaarse perioden, als er minder water is dan verwacht, passen de *Junta de Usuarios* en de ATDR samen de watertoewijzingen aan. In Chancay-Lambayeque worden er dan een vast aantal uren per hectare geprogrammeerd met een vaste irrigatie interval van 15 dagen. Het aantal uren dat wordt toegewezen is proportioneel kleiner bij een groter landbezit. Boeren kunnen er dan voor kiezen een deel van hun land voldoende te irrigeren of hun gehele perceel deficiënt te irrigeren. In Jequetepeque komt waterschaarste minder als een verrassing, omdat het reservoir groter is. Hier worden bepaalde stukken land (*campos*) uitgesloten van het verbouwen van rijst als er weinig water in het reservoir zit.

In hoofdstuk 5 wordt de volumetrische waterdistributie geëvalueerd. Eerst wordt er een analysekader gepresenteerd. In dit analysekader staan drie factoren centraal: de infrastructuur, het waterverdeel-personeel, en de watergebruikers. Echter, op de eerste plaats is er gekeken naar de relatieve waterbeschikbaarheid. Als er meer dan anderhalf maal meer water beschikbaar is dan nodig voor de gewassen kan water gebruikt worden als substituut voor controle. Chancay-Lambayeque kan beschouwd worden als een 'nachtmerrie'-systeem: handmatige 'undershot' verdeelwerken, weinig meetstructuren, open kanalen, onregelmatige rivierafvoeren, en een gecompliceerd irrigatiebeurten-systeem op aanvraag van de 22.000 watergebruikers. Desondanks kwam de gemeten waterdistributie erg dicht bij de geprogrammeerde waterdistributie. Dit kan verklaard worden door de grote kunde van het waterdistributie-personeel en de verantwoording die het bestuur moet afleggen naar de watergebruikers. Dit sterke mechanisme van verantwoording kwam tot stand doordat het bestuur bij aankomende verkiezingen herkozen wenste te worden in verband met het inkomen uit illegale verkoop van water. Ook radio en kranten werden gebruikt om verantwoording af te dwingen. In Jequetepeque werd meestal meer water afgeleverd dan geprogrammeerd. Dit hield verband met de ruime beschikbaarheid van water.

Hoofdstuk 6 gaat in op het financieel beheer van de twee irrigatiesystemen. De Algemene Vergadering van de *Comisiones* stelt de hoogte van de heffing vast. De heffingen worden betaald aan de *Junta de Usuarios*, die vervolgens het geld verdeelt over de verschillende gebruikers en overheidsorganisaties. In Chancay-Lambayeque werd in de periode van 1993 tot 1998 meer dan negentig procent van de heffingen daadwerkelijk (per volume) betaald. Dit kon bereikt worden door de hoge mate van technische en sociale controle over het water. Alleen de suikerriet coöperaties in het begin van het systeem namen water zonder de heffing te betalen. Een nadeel van de volumetrische heffing is dat bij weinig rivierafvoer er ook weinig inkomen voor de organisaties is. In Jequetepeque waren de betalingen moeilijker af te dwingen vanwege de ruime water beschikbaarheid. De *Junta* kon echter de betaling afdwingen in het begin van het rijstgroeiseizoen. Het land was dan nog droog en de boeren moesten voor een bepaalde datum hun rijstzaaibedden klaar hebben in verband met lage temperaturen die de oogst verminderen aan het eind van het seizoen. Door een strikte controle over deze eerste water beurten kon de *Junta* in Jequetepeque de betaling van de heffingen (van het voorafgaande jaar) afdwingen. Deze combinatie van technische, omgevings-, en institutionele elementen die de betaling afdwingen wordt in de studie een 'verplicht passeerpunt' genoemd.

In totaal werd ieder jaar tussen de 1,5 en 3,0 miljoen dollar aan heffingen betaald. Dit was ongeveer voldoende voor het gebruik en onderhoud van het systeem en de belastingen die betaald moesten worden. Echter, de verdeling over de organisaties was dusdanig dat de *Comisiones* te weinig fondsen hadden voor onderhoud. Het onderhoud van de tertiaire en hoofdkanalen was echter voldoende. Enige subsidie voor onderhoud kwam binnen via een herstelproject na de El Niño overstromingen van 1998.

Hoofdstuk 7 gaat in op het functioneren en de effecten van volumetrisch waterbeheer. Er kan worden geconcludeerd dat het waterbeheer in Chancay-Lambayeque inderdaad volumetrisch is. In Jequetepeque wordt het water volumetrisch toegekend en verdeeld (op hoofdsysteem niveau), maar niet betaald naar gebruikt volume. In beide systemen zijn er twee belangrijke krachten die waterbeheer beïnvloeden. Op de eerste plaats de geschiedenis van de instituties en infrastructuur. Ondanks de abrupte veranderingen in de institutionele opzet is er ook veel continuïteit in de lange geschiedenis die heeft bijgedragen aan de legitimiteit van de regels en de functionaliteit van de infrastructuur. Op de tweede plaats de machtsbalans tussen de verschillende gebruikers- en overheidsorganisaties. De structuur van het bestuur was vrijwel geheel volgens de officiële regels uit de Water Wet. Bijvoorbeeld alleen de hoogte van de heffingen en boetes was niet conform de wet. Handhaving van de regels werd deels afgedwongen door sociale controle tussen 'gelijkwaardige' partijen, bijvoorbeeld de boeren in het tertiaire vak of de ingenieurs van de *Comisiones*. De regels werden ook gehandhaafd door de overheidsinstanties ATDR en AACH. Zij speelden een rol in het oplossen van conflicten binnen de gebruikersorganisaties. Het straffen van overtredingen werd op een 'politieke' manier gebruikt: een boete van de ATDR betekent dat een watergebruiker uitgesloten wordt voor een volgende verkiezing van het bestuur.

Het effect van betalen per volume op de productiviteit van water is klein. De algehele waterbeschikbaarheid is veel belangrijker. In Chancay-Lambayeque wordt het water veel wijder 'uitgesmeerd'. Dat maakt het water productiever. Het betalen per volume werkte nadelig uit voor armen boeren. Zij hebben vaak geen geld om op tijd hun irrigatiebeurten te kunnen aanvragen. Echter, de kosten voor water zijn maar 5 tot 10 procent van de totale productiekosten. En een voordeel van de betaling per beurt is dat de aflevering beter afgedwongen kan worden door de *Comisiones*.

In hoofdstuk 8 wordt geconcludeerd dat het machtsevenwicht tussen de verschillende gebruikersorganisaties, de privé bedrijven en de overheidsinstanties een functionele entiteit bewerkstelligt. De algemene overheidsregels werden gevolgd, maar de regels voor watertoekenning, onderhoud, en heffingen werden lokaal verder uitgewerkt. Er kan geconcludeerd worden dat het gebruikte analytische kader en de gebruikte onderzoeksmethoden nuttig waren bij het ontrafelen en begrijpen van de complexe structuur van het waterbeheer.

Curriculum Vitae

Jeroen Vos was born in 1969 in Tilburg, The Netherlands. After completing high school in 1988 he started the study Irrigation Engineering at the Wageningen Agricultural University. At that time the interdisciplinary approach was well established at the Irrigation and Soil and Water Conservation Group. Courses included both technical engineering as well as organisational, social, political and economic aspects of water management. In 1992 he spent his practical period in Ecuador. Together with a local women's organisation he designed and constructed small sprinkler irrigation systems. In 1994 he completed his study with a MSc research on participation of different stakeholders in government interventions in small-scale irrigation systems in the Hills of Nepal.

From 1995 to 1996 he was assistant of the two directors of the Dutch non-governmental donor organisation HIVOS. Helping and observing the directors provided many insights in the practice of daily management. End of 1996 he embarked on a study of the irrigation management transfer and rural transformations in Romania with a grand from Nuffic. The large-scale sprinkler systems, which use water pumped from the Danube river, were economically hardly viable after the collapse of the State-planned economic system. It proved to be quite hard to do research on the politically sensitive subject of transfer of the irrigation systems. Nevertheless, the study made clear that management turnover was much more complicated than presented by scholars and promoted by the World Bank and other international organisations.

In 1997 he joint the Irrigation and Water Engineering Group of the Wageningen University as research assistant to conduct a PhD research and assist in lecturing irrigation courses to BSc and MSc students. The fieldwork of the PhD study was executed from August 1998 to June 2000 in the North Coast of Peru. The water management in the two large-scale irrigation systems Chancay-Lambayeque and Jequetepeque was compared. The field research was assisted by the local NGO IMAR Costa Norte. This NGO trained local farmers, the elected board and their staff in irrigation water management. The practical and interventional work of IMAR combined and completed well the more academic study of the irrigation management. Back in Wageningen, thesis writing, lecturing, course material development and collaboration with French and Spanish irrigation research groups were alternating activities.

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