Dodota Spate Irrigation System
Ethiopia

A case study of
Spate Irrigation Management
and Livelihood options

M.Sc. Thesis by John-Paul van den Ham

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Master thesis Irrigation and Water Engineering submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands

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SUMMARY

This case study focuses on the water management of the Dodota spate irrigation system, the first large scale spate irrigation system in Ethiopia. This system in the Oromia state has been recently designed and constructed to establish food-self sufficiency in an area chronically affected by food deficits and supported by food aid for over 25 years. The following main research question guided this study: How is water management taking place in the new Dodota spate irrigation system and what are the impacts and effects for irrigation, soil conservation practices, and production?

Spate irrigation is amongst the oldest form of irrigation for which floods are diverted through wadi´s for direct irrigation. It has specific site characteristics and is known for its uncertain water availability and scale of sedimentation and the challenges of infrastructure and the water distribution given its severe operation and maintenance requirements.

The socio-technical framework of Mollinga (2003) is used to understand how the technological and social dimension are connected and interrelated. In the study area, the agrarian structure is recognized by the dependency on food aid and a poor developed status. Here the Safety Net Programme and several governmental structures and extension services have supported the farmers to sustain and improve their livelihood. Farmers were completely dependent on rainfed agriculture and failed to produce sufficient food. With the new irrigation facilities livelihoods are expected to improve. The new system has a sophisticated design and deals with erosion, sedimentation and natural drainage, and even allows for water distribution with upstream control. But it is impossible to be managed by the farmers only, since it requires heavy machinery and skills for the operation and maintenance. For this reason the organisational activities have been divided, based on the spatial dimension of the scheme; the government will manage at scheme level and the Water User Association (WUA) at field level. These forms of organisations need to contribute efficiently and are both responsible for proper management to enable efficient and fair irrigation.

At scheme level, the rules related to the allocation and delivery of water, need to be coordinated and controlled by the Oromia Water Works Construction Enterprise (OWWCE) in agreement with the WUAs in the District Board of Management. The establishment of the WUAs will take care of the coordination and control of the water distribution, maintenance and operation in the tertiary units. To make proper and successful use of the new system, adaptation in land and water rights and cultivation practices of the farmers is essential. The land rights are established for the study area, but water rights are completely new. Last year 300ha was irrigated. This first irrigation experience showed that farmers were willing and motivated to cooperate, but at the same time their cultivation and irrigation practices were lacking behind. Here the state and irrigation institutions play an important role to involve the farmers in the operation and maintenance of the system and to transform their livelihoods. The Sustainable Livelihood Approach (DFID, 2002) was used to study this and showed that the transforming structures and processes need to operate at all levels.

The success of the system will depend on the actual performance of the system to enable farmers to increase their production. Better insight in the actual water division and distribution is needed and by monitoring the water availability and the crop water requirements, water management can be improved. This study has indicated that it is sustainable to use pre-irrigation for a single crop season. But in the future the individual choices of farmers will change the irrigation requirements in the tertiary units, the branch canals and for the scheme as a whole and therefore, will be important to consider. Sustainable development focuses besides technology, mainly on the suitable management of the scheme, to deal with issues and to realise positive social effects, in order to sustain proper operation and maintenance. Hereby it is important to support the transformation structures with required education and training. Sustainable management needs clear policies and guidelines, to establish fair water sharing to improve the livelihood of all farmers.

ACKNOWLEDGEMENTS

The realisation of this thesis has been the greatest work of my life. It was an enormous adventure and taught me more than I could have imagined. I am grateful to achieve this final work, but it would not have been possible without the support of many others. First of all I would like to thank my supervisor Dr. Frank van Steenbergen, who gave me this opportunity. In a certain way it reminded me of a so called ‘once in a life time opportunity’ in which things are as they should be. Six weeks after meeting Frank I was on my way to Ethiopia. This was my third visit to Africa, but certainly the most impressive one.

During my stay I have been surrounded by several professionals who supported my study. Some even became close friends. Here I would like to mention some names in particular, especially Taye Alemayehu, who gave me trust, respect and support to find my way in this part of the world. During my stay I visited the Dodota system and stayed at the engineering base camp, here I met the Chief Executive Engineer, Jagema Kenine, who intensively supported my study and became a close friend. He introduced me to many people and showed me the local cultures and traditions. Also I would like to thank the project manager of the OWWCE, Feyissa Benti and field engineer Welkite, for their support, hospitality and kindness. With joy I remember my stay. I have not been in Ethiopia for quite some time now, but I hope to meet them again and I wish health and prosperity to all.

For supervision and advice I would like to thank Prof. Linden Vincent, who was willing to guide me. Without her professional support I would have probably lost the overview. She had patience and helped me to find my way, our discussions made me enthusiastic and passionate.

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ACRONYMS

ARDO	Agricultural Rural Development Office (district)
BARD	Bureau of Agricultural and Rural Development
CPCB	Cooperation Promotion Commission Bureau
CFSTF	Community Food Security Task Force
CWR	Crop Water Requirement
DA	Development Agent
EARI	Ethiopian Agricultural Research Institute
FAO	Food and Agriculture Organisation
FSL	Full Supply Level
GIS	Geographic Information System
ID	Irrigation Department
IFAD	International Fund for Agricultural Development
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
KFSTF	Kebele Food Security Task Force
MKI	Melkasa Research Institute
MoWR	Ministry of Water Resource
MoA	Ministry of Agriculture
MRI	Melkasa Research Institute
NCCR	National Centre of Competence in Research
ODPPC	Oromia Disaster Prevention and Preparedness Commission
OIDA	Oromia Irrigation department authority
OWRB	Oromia Water Resource Bureau
OWWCE	Oromia Water Works Construction Enterprise
OWWDSE	Oromia Water Works Design and Supervision Enterprise
PA	Peasant Association
PSNP	Productivity Safety Net Programme
WFP	World Food Programme
WFSTF	Woreda Food Security Task Force
WRDO	Woreda Rural Development Office
WUA	Water User Association
WUC	Water User Cooperation
WUGL	Water User Group Leader

1 INTRODUCTION

1.1 Problem statement

In Ethiopia spate irrigation is recently promoted by the government and farmers' initiatives. Feasibility studies suggest that it can support many farmers in large command areas. For this and several other reasons spate irrigation is gaining importance. The increase of world food prices, the reduced grain surpluses and imports and the consequent reduction of food aid supply alarms Ethiopia, a country depending on food aid for many years. Given the high relevance of food security, for Ethiopia in general and for the study area in particular, spate irrigation is foreseen as having potential to reduce poverty and establish food security. As many farmers may potentially access this system, development can have great impact and bring further socio-economic development.

This research focuses on understanding of water management, local irrigation practices and effects on farmers' livelihood options. Therefore, to analyse these interactions, a case study was carried out with a main focus on a new system under development: the Dodota spate irrigation system in the Oromia State. The aim of this research, within a project initiated by MetaMeta[1], is to contribute to improve design choices and livelihood options under spate irrigation systems, in both national and international irrigation development programs. For Ethiopia, this research can assist the debate on whether new systems are as manageable, equitable, reliable and environmentally friendly as Ethiopian policy has promoted.

1.2 Background

Ethiopia is situated in the horn of Africa, and is bordered by Sudan, Kenya, Somalia, Djibouti and Eritrea. The surface area is more than one million square kilometres and the country stretches from latitude 3° North to latitude 15° North of the equator and from 33° East to 48° East longitudes (MoWR, 2004). It has a large population of approximately 77.1 million people with an annual growth rate of 2.4% (FAO, 2008). The country has nine regional governments, Tigray, Afar, Amhara, Oromia, Somalia, Benshangul-Gumuz, Southern Nations Nationalities and Peoples, Gambella, Harari and two city states Addis Ababa and Dire Dawa. Ethiopia belongs to one of the poorest African countries, with 52% of the population living below the national poverty line (MoWR, 2004) and 31.3% of the population living below US$1 a day (World Bank in Teshome, 2003 p.24).

Ethiopia is known as a 'water tower' given its peculiar geomorphology, since it has a vast central high plateau surrounded by lowlands. The climate conditions are significantly influenced by latitude, altitude, winds and humidity with varying magnitude. Altitude is the most important factor for the climatic condition of the country. Ethiopia has different main climate regions; dry; tropical rainy; and a temperate rainy region.

Since the 1950's, the Ethiopian government has tried to reform, modernise and transform the economy. The interventions made, by top down approaches, include the 1975 land reform, resettlement, villagisation and the cooperativization of agricultural extension programs. In 1973, 1984, 1994 and 2003 the country was suffering from famines and food shortages. The main agricultural challenges are a lack of storage of water and large spatial and temporal variations in rainfall. For most farmers there is not enough water to produce more than one

[1] MetaMeta is a research & consultancy company focussed on the international resource management and development sector and operates in the spate irrigation network. It has profound knowledge and experiences in spate irrigation obtained by field work & research in Pakistan. With these perspectives and experiences it is currently undertaken on request of IFAD a global assessment of the potentials of spate irrigation.

rainfed crop a year and besides this, there are frequent dry spells and droughts causing crop failure, resulting in chronic food shortages (Awulachew et al, 2007).

Since 1991, Ethiopia has a federal administrative structure, organised in a central federal government and regional governments. In 1999 a new irrigation policy was introduced, this irrigation development policy is situated under a general water resource management policy. On the whole, this policy aims to achieve food security at national level and focuses on small, medium and large scale irrigated agriculture to improve production and promote sustainable, manageable, equitable, reliable and environment-friendly irrigation systems which make efficient use of water (MoWR in Teshome, 2003 p.43).

According to the World Bank, the agricultural sector is the leading sector in the Ethiopian economy, 47.7 percent of the total GDP, as compared to 13.3 percent from industry and 39 percent from services (Awulachew et al, 2007 p.1). More than 85% of the total labour force is working in the agricultural sector (CSA in Awulachew et al, 2007 p.1). To improve these livelihoods, the International Fund for Agricultural Development (IFAD) contributes with technical assistance and financial support. IFAD's strategy in Ethiopia focuses on; "supporting investment programmes with the greatest potential impact on sustainable household food security and on the incomes of rural poor people, particularly small-scale farmers and herders, and women in all categories" (IFAD, 2008). Means to help improve the production and income of farmers can be irrigation. In fact, irrigation can improve yields significantly and even double them as indicated by farmers from the Wadi Laba spate irrigation system in Eritrea (Haile, 2007). Besides this, the total irrigated area is only 197 thousand ha while the country's irrigation potential is about 2.5 million ha (Teshome, 2003). There is keen interest for spate irrigation, so far used in the poorest areas. Given its potential in lowland development, it is thought significant improvements in production can be realised.

Spate irrigation is among the oldest forms of irrigation and used in several arid and semi-arid regions of the world. Spate floods originate from accumulated rainfall over mountainous catchments and run through the lower areas. Spate irrigation involves the diversion, conveyance, and application of the spate flood to the irrigated fields. This is established by simple earthen, brushwood, gabion or concrete structures. The importance of spate irrigation is not to be underestimated since for several regions spate irrigation is also the only method for irrigation and therefore essential for achieving sufficient yields. Spate irrigation can be found in parts of Africa, the Middle East, West India and Latin America. FAO Aquastat has collected data obtained from governments and estimated there is a total area of 3.15 million ha of spate irrigation over 10 countries representing 13% of their irrigated area. However, it is believed that "more informal" areas of small-farm spate irrigation can be found in other countries such as Sudan, Ethiopia, Egypt, Kenya, Mauritania and Senegal as well as Chile and Bolivia (El Askari, 2005)". One of the main characteristics of spate irrigation is the unpredictability of the flood water in occurrence and amount and its high sediment load and destructive nature (Haile, 2007). This makes the development of sustainable irrigation management challenging. In Ethiopia due to the population pressure, shortage of food and the new irrigation policies, pressure on water resources becomes more severe. The new policies aim at fair and equitable distribution of water. A question is how this is being established by the farmers, since the water has to be directly diverted and shared fairly.

The Dodota irrigation scheme is situated in the Arsi zone, south from Nazret and between Dera and Sire. The potential irrigated area is about 5000ha but it is still under development by the Oromia government. The system is a spate irrigation system with permanent concrete (heavy duty) structures, which should supply water for more than 5 months every year, by taking water from the Boru river. The government is investing in development of the system but how are they doing this and what are their objectives? Furthermore, what are the strategies of the farmers living in the development area? In this research the following main research question will guide the study: *How is water management taking place in the new Dodota spate irrigation system and what are the impacts on irrigation, water conservation and production?*

1.3 Study area

Ethiopia has nine National Regional States as well as the two cities with administrative councils. The regional states are divided in zones, further divided in districts, also called *woredas* and last but not least divided in municipalities which are called *kebeles*. In total there are 580 Woredas and around 15,000 Kebeles (5000 urban and 10,000 rural) (MoWR, 2004). Oromia State with an estimated population of 26,5 million people, is the highest populated state and it is also the largest state in terms of land area (CSA, 2005). The state has currently 199 perennial irrigation schemes with 4 large-scale[2] schemes. In total, these systems cover a total irrigated area of 33.765,19ha (Awulachew et al, 2007).

The Boru Dodota Spate Irrigation development project is located in the Arsi Zone of the Oromia state shown in Figure 1.1. The scheme is in the south of Nazret[3] and has a potential command area of 5000ha. The construction started in 2006, and from 2008 onwards this large new system is expected to contribute significantly to increased production. There are estimated 4.172 households as beneficiaries, representing a population of 30.073 people. The crops which could be grown are carrot, beetroot, potato, onion, cabbage, maize, sorghum, soybean and cereals, wheat and barley (Aman et al, 2006).

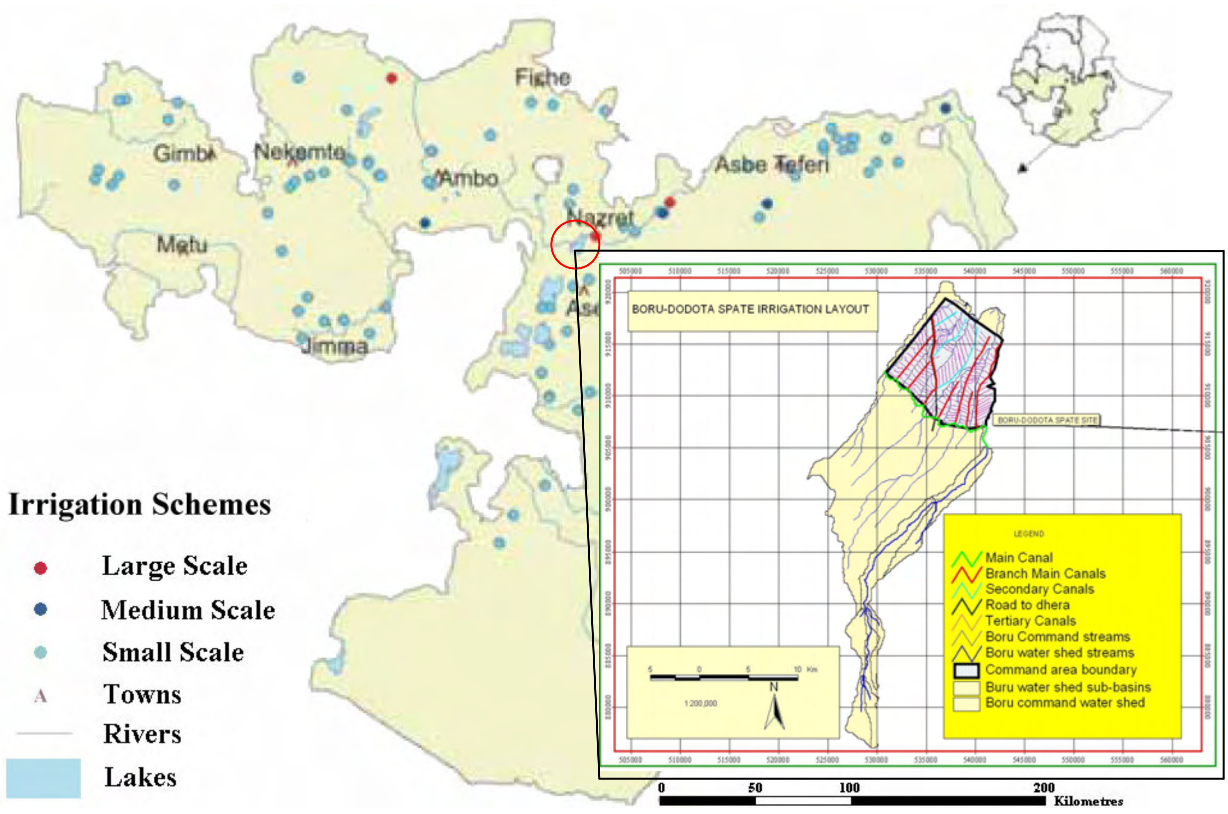


Figure 1.1: Existing perennial irrigation schemes in Oromia State (Awulachew et al, 2007)

(schemes under construction, non operational or suspended are not depicted)

[2] For large schemes the command areas vary between 8960ha and 3500ha, Metahara-Abadiy is the largest scheme and Wonji Shoa is the second largest scheme with 5925ha.
[3] Nazret is the 3rd largest city, after Addis Ababa and Dire Dawa.

1.4 Conceptual framework

The research focuses on the interrelation between water management in the spate irrigation system, the farmer's emergent irrigation practices and their impact on livelihood strategies. Many concepts are developed for understanding how irrigation systems work. The socio-technical approach of Vincent and Mollinga discussed in Teshome (2003:7) looks at irrigation systems as socio/technical systems in nature and uses an interdisciplinary approach to address the technical and social dimension simultaneously. Mollinga in Teshome (2003:7) expressed the social dimension of technology in three dimensions: social requirements for use; social construction; and social effects of irrigation technologies. In the first dimension, the social requirements for use become agreements and rules that shape the "new" water management. Kimani & Ubels in Pant (2000:15) showed the three courses of action which are possible if the technical aspects and social aspects do not match:

- Adapt the technical design so that organisational requirements better fit in social patterns.
- Develop new organisational arrangements that link technical requirements and organisational capacities.
- Seek certain social or organisational changes that will result in new forms of organisation.

The second social dimension makes clear how "irrigation technology is an expression or materialisation of norms" (Perez, 2005:20). The last dimension shows the effect of irrigation to improve people's living conditions by improving the production and providing water. In 2003 Mollinga made a descriptive model of the socio/technical view in which the irrigation systems is placed in its context, the 'agro-ecological system and technological infrastructure' (AE&TI), 'agrarian structure' (AS) and 'state and institutions of civil society' (S&CS). Central to Figure 1.2 are the basic elements of irrigation systems, 'water' (resource), irrigation 'technology' (tools) and 'people and forms of organization' (social component). Others who have discussed forms of organisation in relation to technology and water include Ostrom and Uphoff. Pant (2000:15) noted that ostrom provides an analytical framework of institutions for governance of irrigation systems, with three nested sets of rules which are necessary for the effective functioning of the irrigation system. The operational rules govern the daily use of monitoring water activities of others and rewards and sanctions for the combination of action and outcomes. Collective choice rules confirm how schemes should be operated and managed. Constitutional choice rules determine who is able to participate in a scheme and who will draw up the operational and collective choice rules (Ostrom in Pant, 2000 p.15). Pant (2000:16) describes that Uphoff tries to understand the system from what has to be done and looks from a functional point of view. This helps to look at roles and tasks in irrigation. He described irrigation as a ' socio-technical process' in which both human and physical aspects interact. He studies management of irrigation systems in three dimensions, based on group actions performing irrigation tasks; control structures (design, construction, operation, maintenance), organizational activities, (communication, resource mobilization, maintenance, conflict management,) and water use activities (distribution, allocation, acquisition, drainage), (Uphoff in Pant, 2000 p.16).

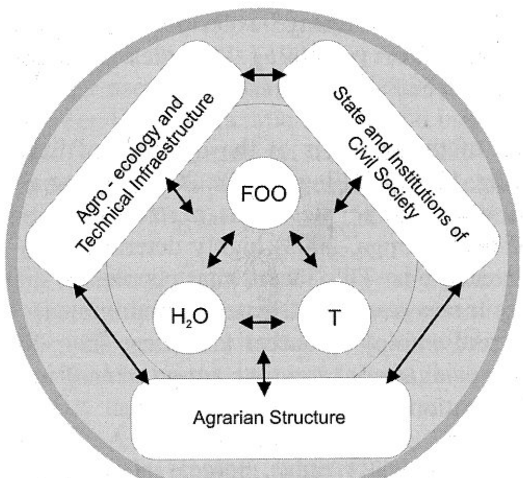


Figure 1.2: Sociotechnical view of irrigation activities and context (Mollinga, 2003)

The focus of this research is to understand how this irrigation scheme is managed and operated. The design choices and construction of the system have implications on how this system can and should be managed and how it can be utilized by the farmers. For this reason the concept of water management of Gerbrandy & Hoogendam (Gerbrandy & Hoogendam in Pérez, 2005 p. 23) is used, which is based on irrigation systems in Bolivia; *"Water management is a form of social interaction: among different stakeholders, using different methods, resources and strategies,*

- *about water use and distribution activities,*
- *taking place in a given socio-technical system, consisting of a series of settings for interaction, which have:*

  -a spatial dimension in terms of the social hydraulic levels of the irrigation system (system, group of households, households), and

  -a time dimension, linked to the agro-ecological cycle and the water delivery rate and are

  -rooted in the culture, in the agrarian structure, in the institutional infrastructure of public and private entities and in material infrastructure (ecology, technology), continually produced and transformed through interaction."

In this concept the irrigation system is imbedded in the rural community and it is referred to as; 'communal irrigation system' (Coward & Levine in Pérez, 2005 p.23). To understand how operational management will take place, a closer look to water rights, organisation, distribution and operation and maintenance is essential.

Water rights; Water rights are defined as "authorized demands to use (part of) a flow of water, including certain privileges, restrictions, obligations and sanctions accompanying this authorisation, among which a key element is the power to take part in collective decision-making about system management and direction" (Beccar cited in Teshome, 2003 p.14)

Organisations; group of individuals, bound together by a shared set of rules, who come together to achieve a common objective (Steenbergen, 1997). *Institutions*; The set of rules actually used (working rules or rules-in-use) by a set of individuals to organize repetitive activities that produce outcomes affecting those individuals and potentially affecting others (Ostrom in Steenbergen, 1997)

Distribution and Operation; Distribution comprises all infrastructure management activities (opening gates, regulating flow, etc.) all social activities that users organise to distribute water (delegating responsibilities, overseeing distribution) and the norms, agreements and criteria governing delivery of water. The two main included aspects of the concept are infrastructure operation and organisation and agreements for water distribution delivery (Claure & Gutierrez in Pérez, 2005 p.26). Operation concerns the activities to control the flow of water through structures and monitor and regulate these flows, to flow as expected (Pérez, 2005:47).

The Dodota irrigation system studied is not finished and still under construction. It is a large scale system and it is realised by a construction enterprise which has built permanent and heavy structures made in concrete and steel. The modern[4] irrigation structure in this large system also needs proper *maintenance* to keep it running. According to (Carruther and Morrison in Gutierrez, 2005 p.25) maintenance is a management response to the deterioration

[4] Haile (2007, p.43), defined these structures as "*Modern irrigation structures",* since they are constructed with external intellectual and financial investment, a combination of local and imported materials from abroad or from within the country and little contribution from the local farming community in terms of skill, material or financial resources.

of the physical condition of the irrigation system that threatens to make it impossible to achieve operational targets.

The implementation of this irrigation system is funded by the European Union to address critical and chronically dependent food insecure areas, not only by giving food aid but also through the development of an irrigation system. This implies the essential effect of irrigation to improve the livelihood of the farmers who benefit from it. In order to have a relation between the impact of irrigation, the third dimension of Mollinga (2003) and livelihood aspect, the concept of the sustainable livelihood analysis is used. This concept is useful to assess the transformation in livelihoods and to distinguish the structures and processes involved. The vulnerability context forms the external environment in which people exist and gain importance through direct impacts upon people's asset status (Devereux in Kollmair and Gamper 2002:5). The new irrigation system is a new external technology, which can bring opportunities to secure livelihoods. Structures can be described as the hardware "that set and implement policy and legislation, deliver services, purchases, trade and perform all manner of other functions that affect livelihoods" (DFID, 1999:21). In this sense, also the importance of food security with food production and food aid can be understood. Processes are complementary to structures and are considered as the "software" determining how structures and individuals operate and interact. The livelihood concept is shown in Figure 1.3 is based on five assets; Human, social, natural, financial and physical capital. According to DFID, "people's access to different levels and combinations of assets, is probably the major influence on their choice of livelihood strategies" (DFID, 1999:23).

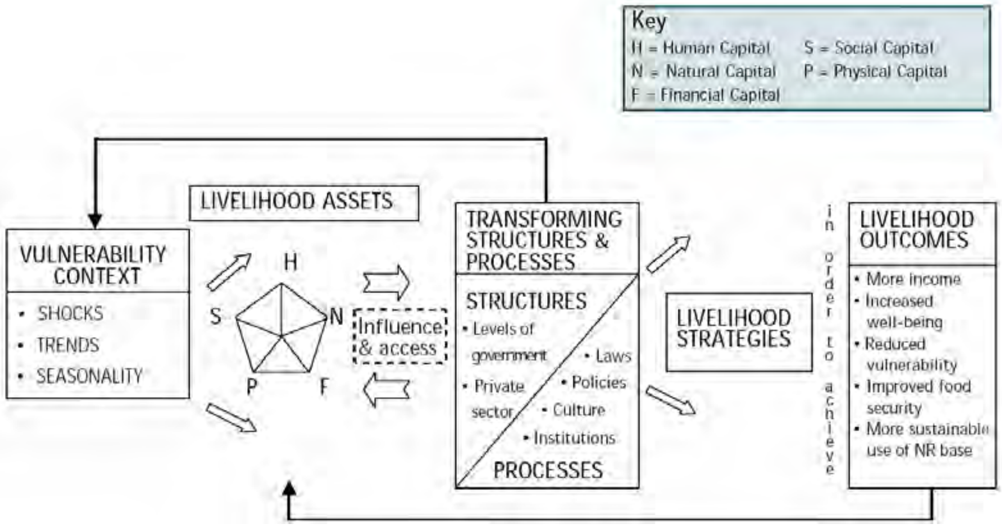


Figure 1.3: Sustainable Livelihoods Approach (DFID,2002)

It is essential to have secure access to assets to be able to have a sustainable livelihood. According to Chambers and Conway in Kollmair and Gamper (2002:3) "A livelihood is sustainable when it can cope with and recover from stresses and shocks as well as maintain or enhance its capabilities and assets, both now and in the future, without undermining the natural resource base". Livelihood strategies are dynamic processes because of changing needs and or circumstances. For this reason, the concept will be useful, to see which activities the people will combine in relation to the new system and the possibilities. The main focus will be on the structures and processes emerging in the new system, which influence the assets and choices of livelihood strategies. In addition as the system is very new, real livelihood impacts are still emerging. This also gives reason to focus on transforming structures and processes, as shown in Figure 1.3. For a new scheme like Dodota, a core dynamic link across these frameworks is the establishment of structures, rules and institutions. A critical question is not just what rules but what processes occur to enable their emergence and embeddedness.

1.5 Problem definition

The Oromia government in Ethiopia is designing and constructing a new spate irrigation system in the Arsi Zone. The development of the irrigation system is initiated by the government of Ethiopia. This region was a known marginal agricultural area depending on food aid. In the new situation, the system will be semi-perennial receiving constant flow from the period April to September. In this case, the new irrigation scheme will allow the farmers to have access to more water and for a longer period. Currently the main and secondary channels are finished and in 2007 already, a pre-irrigation assessment[5] of 300ha has taken place. This was the only part which could already receive irrigation water. One of the main characteristics of spate irrigation is the unreliability of predicting the amount of water that will be available. Also in this system it is uncertain whether enough water will be available to irrigate 5000ha. In this sense, the design and construction, the water management of the system and the users will have to interact to find the optimum situation. Many new questions arise about water management of the system and also about the involvement of farmers to manage their fields.

1.6 Objectives

The aim of this research is to understand the construction and design of the system, the water management and the field- and soil management of farmers in the Dodota spate irrigation system. This case study will be used to analyse, how livelihood strategies of farmers interacts with the water management and the infrastructure of the Dodota spate irrigation system. With a precise documentation, MetaMeta can contribute to the better design choices and livelihood options, in both national and international irrigation development programs. The approach to assure food security and poverty elevation in the Ethiopian policy can be reviewed and discussed whether it is as manageable, equitable, reliable and environmentally friendly as promoted.

1.7 Research questions

1.7.1 Main research questions

How is water management taking place in the new Dodota spate irrigation system and what are the impacts and effects for irrigation, soil conservation practices, and production?

1.7.2 Sub questions

How is water management taking place in the Dodota spate irrigation system?
- What infrastructure choices and design principles have been used in the system?
- How is operation and maintenance established?
- How are land- and water distribution rules (rights) arranged?
- How is water distributed over the command area throughout the irrigation season?

How are irrigation, soil conservation practices and production shaped by main system water distribution?
- How is water and soil moisture managed at field level?
- Which crop(s) patterns are likely and preferable to be used?
- Which main livelihood strategies can be distinguished? (Among farmers who currently having irrigation and among those anticipating irrigation)

[5] In June 2007, around 300ha have been irrigated with the support of the OIDA.

1.8 Research methodology

1.8.1 Research strategy

For doing research there are five major research strategies, these are; experiments, surveys, archival analysis, histories and case studies. This research was based on a case study of the Dodota spate irrigation system from January until the end of April 2007. After a rapid appraisal of the site, the system, the design, and construction have been thoroughly analysed. The information gathered can be quantitative or qualitative from origin but has been mainly qualitative in this study. In order to check and validate or for triangulation (cross-checking) multiple resources were used. Besides the collection of secondary data and field observations, information was gathered through personal interviews. The people involved in the implementation and the organisation of the system, and the users were questioned to understand how the system works and interacts. To get people's confidence in order to gain reliable information and because of the local language, the construction engineers joined the interviews with farmers and some experts. The involvement of the engineers turned out to be successful for the generation of information through the interaction with the local actors.

The Rapid Appraisal method was of great significance in order to analyse the system and to have an understanding of the situation. The focus was solely to identify and evaluate. In order to have a better understanding of farmers, their requirements and interest, the PRDA method (Participatory Rapid Diagnosis and Action Planning of Irrigated Agricultural systems) was used (Schans and Lempérière, 2006). This is a method for analyzing and improving the performance of an irrigation scheme together with the farmer. With PRA-tools system diagnoses can be acquired to obtain the strong and weak points of the system. Other tools which can be useful for research and data analysis are stakeholder analysis, irrigation and drainage system mapping, water resource mapping, crop rotation calendar, Venn diagram, cost benefit analysis, organisational analysis, input and market chain analysis, the cause and effect diagram, the multi criteria analysis, trend analysis and benchmarking. The techniques which were used in this study are;

Semi structured interviews	Essentially guided interviews but allows a conservation to develop naturally
Transects	Walk through an area, observe, listen and question
Time line	Identify important occurrences and relate to current processes
Seasonality diagramming	Identify interactions related to seasonal issues
Matrix ranking	Ranking relative merits by farmers (crop production)

First, there were general visits in different villages from which Amigna Debaso was selected for detailed study. It was only in this village that farmers already had irrigation and it was also near the base camp which made it reachable without a vehicle, see also Figure 4.16. As an indication of the livelihood insecurity across the area, secondary data was collected on food security, which is mapped in chapter 4. Next to the field study there were many interviews with higher officials and government officials, not close to the site, but mainly in Dera, Nazret or Addis Ababa.

1.8.2 Sources of information

Sources of information for this research included: secondary data, personal observations, and interviews. Information was retrieved from different levels shown in Figure 1.4, such as diverse research centres, international or national institutes, governmental structures or non-governmental structures and or Enterprises.

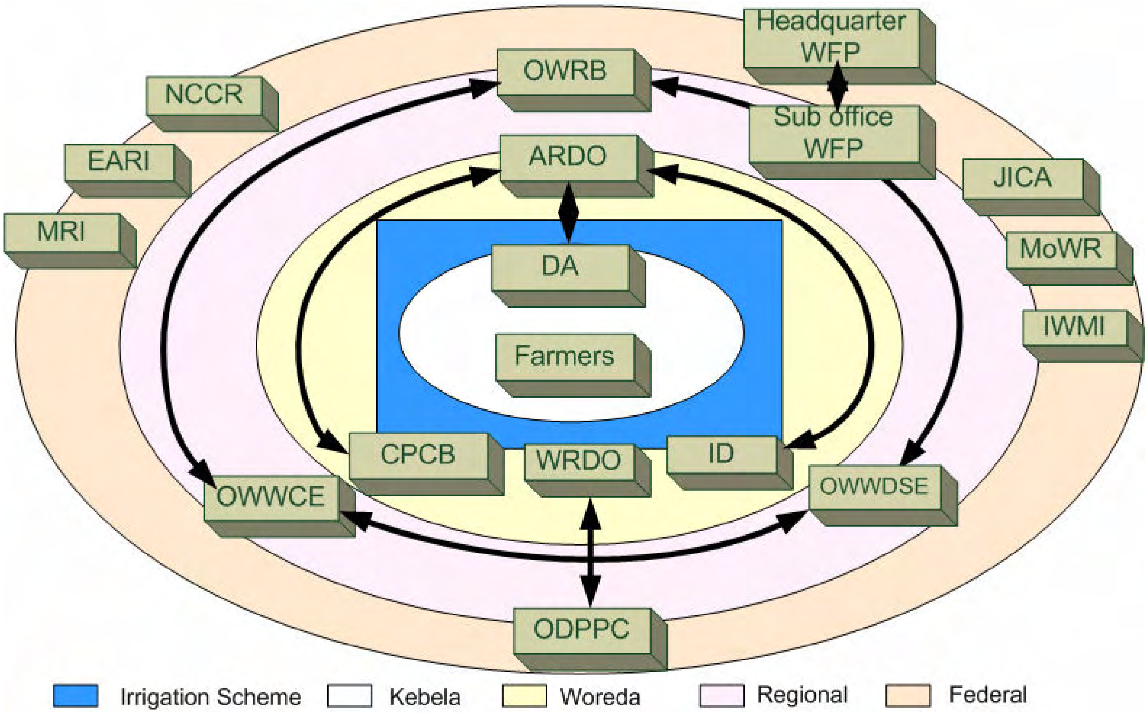


Figure 1.4: Sources of information at different levels

Secondary data: was obtained from; International organisations like the FAO, the World Bank or the International Water Management Institute (IWMI). Also several research institutes, like the Melkasa Research Institute (MRI), the Ethiopian Agriculture research institute (EARI) and the National Centre of Competence in Reseach (NCCR North-South) were of help and were able to give detailed information. Specific Ethiopian regional or local authorities were visited for retrieving information. Several state agencies or ministries were visited, like the Ethiopian Central Statistical Authority, the Ministry of Water Resources (MoWR) and the Ministry of Agriculture (MoA) from which detailed information about the country were obtained. The Japan International Cooperation Agency (JICA) involved in the development of small scale irrigation, had specific information about irrigation practices. From the local administrative unit *woreda* and or from the smallest administrative unit *kebele* very detailed information has been obtained. At *woreda* level, the Agricultural Rural Development Office (ARDO) was of great interest, since it accommodates the Irrigation Department (ID) and the Cooperation Promotion Commission Bureau (CPCB). At *kebele* level, Development Agents (DA) were working for the ARDO. The CPCP and the ID were both involved in the preparation of the farmers for irrigation, by organizing and informing them, and in the implementation of the local management of the Dodota scheme. Besides this the farmers were supported with food aid. In this region was not the United Nations World Food Programme (WFP) active but the Productivity Safety Net Programme (PSNP): here worked the Oromia Disaster Prevention and Preparedness Agency (ODPPC) and the *Woreda* Rural Development Office (WRDO). These agencies were responsible for the coordination of the safety net programme of Food Aid. Since the region is still not food self-sufficient, the programme is of major importance to the livelihood of the farmers and plays a role in the field preparation for irrigation.

For retrieving information about the irrigation project and the irrigation practices, the Oromia Water Resource Bureau (OWRB), the Oromia Water Works Design and Supervision Enterprise (OWWDSE) and the Oromia Waterworks Construction Enterprise (OWWCE) were contacted. From the Ethiopian Mapping Agency, satellite images and spatial maps were retrieved. To acquire more insights in the practices of Irrigation in the region, a database in geographic information system (GIS) about existing small, medium and large irrigation schemes, created by the IWMI together with other partners. was consulted. Specific data of the Dodota spate irrigation system was retrieved from interviews with the construction engineer at the construction site. With the support of the engineers, it was possible to take a closer look at archives with specific data about the main system and to collect information from Geo-graphical information systems and other software applications.

Personal observation: The Dodata system is designed for a potential local command area of around 5000ha and considered a large scheme. For understanding the physical layout of the system, a closer look at the system was obtained, by walking through the system as constructed and operated so far. The different structures have been distinguished and observed. For visits further away from the base camp a vehicle was necessary. Different villages within the potential area were visited for taking an insightful look at farmer irrigation practices and conservation. The village “Melka Jabbi” was located near the headworks and “Lode Sharbe” in the middle of the scheme. By visiting these different villages it was possible to understand more about existing land use and farmer expectations. The most important and interesting area was the village Amigna Debaso near the base camp which already had irrigation. In 2007, an assessment of pre-irrigation of 300ha had already taken place in Amigna Debaso. In this village information was gathered by taking a closer look at the different farmers’ irrigation practices and how water distribution and irrigation had been carried out.

Interviews: the main interview method was semi-structured and with many different interviews, it turned out to be a major source of information. Besides government officials and engineers, local farmers were interviewed. It was possible to interview the engineers at the base camp and to visit the local farmers. First general visits in several villages were made, to acquire better knowledge and understanding of farmer irrigation and water conservation practices in the project area. Secondly, the village Amigna Debaso was selected, because here pre-irrigation had already taken place. Even though the irrigation experience was very recent and limited, it gave the opportunity to understand people’s ideas and reactions to new technology and water management being introduced. In this way, the functioning of the Dodota system was questioned and the possibilities of the farmers were discussed. This resulted in a better understanding of the different aspects of irrigation.

1.9 Outline of the chapters

After having presented the aim, the theoretical concepts and methodology in this chapter, chapter 2 gives a description of the spate irrigation developments in Ethiopia and documents commonly occurring principles, found in spate irrigation systems emerging over time. Chapter 3 describes the study area and context in which the system is situated and focuses on the agro-ecology, the agrarian structure and the institutions. Chapter 4 gives an overview of the Dodota irrigation system and focus on the infrastructure and management and describes the processes of structures involved in the organization- and water activities. Chapter 5 focuses on the initial changes and transformation in livelihoods of the farmers and their response to the new irrigation scheme and includes first studies of field application and deficiencies. Furthermore is discussed which crops and yields can be anticipated. In chapter 6 the future feasibility and development of irrigation is discussed, based on simple calculations of water supply and water use, to achieve ‘sustainable development’. The final chapter presents the discussion and conclusion of this thesis.

2 SPATE IRRIGATION

Spate irrigation is an ancient method of irrigation with distinctive site characteristics, rights and rules shown in a variety of types of schemes, structures, practices and management. The first section takes a closer look at the development of spate irrigation in Ethiopia. Spate irrigation systems can vary in many ways, the second chapter describes the relation of spate irrigation with specific site characteristics. The third section gives an outline of the different structures which are used in spate irrigation systems to divert and control the spate flows. For diversion and sharing the spate, water rights and distribution rules commonly used are discussed in section four. The final section elaborates on the issues of operation and maintenance in spate irrigation.

2.1 Spate irrigation in Ethiopia

In Ethiopia practices of water harvesting dated back as early as the pre Axumite period, 560 before Christ (Getachew in Alemayehu, 2008). The use of run-off and seasonal floods is a common practice and used mainly in the arid parts of the country. Floods may come several times a year and makes spate irrigation more "evened out[6]" than in other countries. Also some spate irrigation systems use the spate for supplemental irrigation, supporting existing rainfed crops. Schemes can be found in the valleys and plains east of Tigray, parts of Amhara, in the eastern Highlands around Dire Dawa and near Harari in the eastern and western parts of Harerge. Also in the southern regions near lake Ababay and in the south from the Konso region, see Figure 2.1. Almost all traditional systems are small scale and managed by farmers entirely (Alemayehu, 2008).

Figure 2.1: Areas with spate irrigation in Ethiopia (Alemayehu, 2008)

[6] Spate irrigation systems in Ethiopia count on several floods instead of a single flood, the size and amounts of the flood is therefore more spread.

Spate irrigation has received limited interest from development agencies and public authorities, because it is being associated with low value subsistence crops and high risks. The systems support livelihoods of the often poorest segments of the rural population in the Middle East, West Asia, North and East Africa (Steenbergen, 1997). This makes it hard to justify investments in civil engineering works. Furthermore there are hardly any examples of successful interventions which fulfilled the initially expected results due to the complex hydraulics and social organization. However spate irrigation shows an important development potential for arid countries with low incomes (Lawrence and van Steenbergen, 2005). In Eritrea the Ministry of Agriculture has identified spate irrigation as a key component to contribute to the attainment of food self sufficiency and or food security (Haile, 2007). Also in Ethiopia, through improvement of existing traditional systems and the development of unexploited areas, spate irrigation has a promising potential. Nevertheless the government has largely focused on perennial irrigation for small scale irrigation programmes, indeed because of lower risks and higher benefits. On the other hand the government has supported the first example of a new large scale spate irrigation system “The Dodota Spate Irrigation scheme”, which will be the example for other potential areas to be developed.

2.2 Site characteristics

Spate irrigation is described by Lawrence and van Steenbergen (2005:2), as…”an ancient form of water management, involving the diversion of flashy spate floods running off from mountainous catchments using simple deflectors constructed from sand, stones and brushwood on the beds of normally dry wadis”. Spate irrigation systems are found in arid to semi-arid areas with a particular concentrated rainfall across the specific topography of mountains and plains. The flood streams originate from sporadic rainfall in the catchment and come together in ephemeral rivers from which the water is diverted and spread over agricultural land. It has similarities to runoff rainwater harvesting and flood inundation systems[7], but for spate irrigation direct irrigation is the priority objective and water harvesting for soil moisture and recharge of shallow groundwater is secondary. Besides that, there are two more characteristics of spate irrigation, the first is the infrastructure used in spate irrigation to divert the floods, with diversion structures from wadi channels and canals into field bunds. The second is the large number of farmers depending on and needed to contribute to the upkeep of the spate irrigation system. This makes that spate irrigation systems have their own ways of operation and management and a wide range of norms, but a distinction is made between uncontrolled and controlled spate irrigation systems (Lackner and Vincent, 1998). Uncontrolled systems have no control over the water and sediment flow, they are without permanent infrastructure at the headworks or within the system. Most traditional spate irrigation systems are uncontrolled which explains why a powerful flood has its direct impact on the operation and management, as far it can be repaired or needs to be rebuilt completely. Permanent structures in controlled systems can be more resistant and divert greater floods, in general the systems are much larger as well and managed by public agencies.

For the development of a spate irrigation scheme the hydrological and geological situation are important parameters. The magnitude, duration, timing and frequency of flood events from a certain watershed at a certain altitude that will arrive at a certain wadi, as a reliable base flow, semi-perennial or perennial flow can vary enormously. According to the geological situation, highland and lowland systems can be separated. Highlands tend to have smaller limited catchments, steep gradients and a hard unpredictable gravelly flash flood. Lowlands receive the floods from the mountain watershed, have a more gentle slope, finer sediment and a larger command area. The floods coming from the highlands are known to carry large amount of sediment, but the sedimentation loads vary from one place to another. In many systems

[7] Found along valley bottoms, based on residual moisture of floods.

sedimentation problems are prevalent as coarse material blocks structures. Fine silts however can be used for farmers to “produce” their own land, they spread on fields the alluvium carried by the flood, which is very fertile. The differences in hydrology and geology will have its impact on the structures developed, the management for operation and maintenance, and for the water distribution.

Spate irrigation systems are not based on a permanent source (a reservoir, or a perennial river or ground water) of water like in many other irrigation systems. In this sense spate irrigation comes with an inherent uncertainty that makes it difficult to predict the total volume and thus the amount of land irrigated by one flood event. The violent power of floods can be damaging to spate irrigation systems and especially to traditional spate irrigation systems, when most infrastructure is not permanent. Besides the size and force of the flood, the number and sequence of flood events are highly unforeseeable, which makes spate irrigation complex to manage. Spate irrigation in Ethiopia is different from Yemen and Balochistan since farmers there are entirely depending on one or two flood events with supplemental unpredictable rainfall. Because of the reliance on single events, the fields are large and the bunds are 1 to 1.5 meters high. With the high bunds, large quantities of water can be impounded before it infiltrates. Yet in Ethiopia, floods may come several times a year and bunds are low (0.3-0.4 meter), the water can be even distributed through small field canals.

2.3 Structures

Systems can be ordered according to the potential command area of schemes, the size can vary from a couple of hectares up to more than 30.000 hectares (Lawrence and van Steenbergen, 2005). The systems are categorised in small, medium and large scale systems. In Ethiopia the Regional State Oromia has its own division for spate irrigation, according to the complexity and manageability in comparison with perennial irrigation schemes. In this way schemes less then 500ha are considered small schemes. If the system is larger than 500ha and smaller than 2000ha it is called medium. Systems over 2000ha are large scale systems (Alemayehu, 2008). Besides distinction in sizes, the infrastructure of spate irrigation systems can be distinguished in three categories shown in Table 2.1 namely; traditional, improved and modernised systems. In most traditional schemes diversions like deflecting spurs can be found. Canals are usually very short and the bunds are mostly next to the flood channel. The improved systems include rejection spillways after the headworks, flow division structures like the flow throttling structure in main canals and drop structures.

Table 2.1: Different types of spate irrigation schemes and structures

Type of scheme	Headworks	Canal structures	Field structures
Traditional	-Deflecting spurs -Diversion bund intake	-Short canals -Flow division structures	Large bunds
Improved	-Deflecting spurs with rejection spillway -Weir with gabions and gated intakes	-Control structures (Head regulator structures and orifice) , -Division structures (flow throttling structure) -Check/drop structure with of-takes -Canal escapes	Large bunds
Modernised	-Weirs with rejection spillway, sluice gate (flush gate) and sand trap	-Main canal and secondary canals, -Division boxes (permanent soil bund and small diversion weirs) -Check/drop structure with of-takes -Canal escapes	-Tertiary canals -Lower bunds

The structures in the different categories have large differences according to the cost, maintenance requirements and the lifetime[9] of the structure. To reduce cost different materials are used. For traditional schemes local materials are used for construction and repair. Structures are constructed from earth, brushwood, sorghum roots and or sand-filled bags and the like. Modern irrigation structures are made from stone, boulders, masonry and concrete and can have metal control gates. In modernised systems the traditional structures have been replaced by concrete structures; including headworks with a diversion weir and a spillway, sediment sluices and gates. The main canals can be connected to branch canals with diversion boxes. Other diversion type structures such as the semi-permanent soil bund and small diversion weirs can be used as well. The diversion structures at the intake of the river need to divert low flows and spate flows. Sometimes many diversion structures can be found along the wadi, which gives several control points[8] to its water users. If diversion structures upstream have been damaged by large floods, diversions downstream can still be used to divert the flood stream. In many systems the destruction of upstream intake structures gives opportunities for the water users downstream. In this way spate irrigation has a relatively high overall scheme efficiency. The intake should prevent and minimise large uncontrollable floods from entering the canals and limit the entry of high load of coarse sediment. The floods are often carrying huge amounts of sediment, which can be harmful for irrigation structures. Traditional systems are designed to cope with sedimentation since the canal beds and fields build up together. They are also more flexible in relation to permanent structures because they can be extended or reconstructed more easily. For permanent structures sedimentation in the fields causes serious problems, structures can be blocked and command area can be lost, therefore investments in sediment removal structures are essential.

2.4 Rights and rules

In spate irrigation uncertainty and unpredictability are inherent, for this reason rights and rules are needed, to support the regulation of relations and the access and use of flood water. The descriptions of rights differ from perennial systems as a quantifiable entitlements or fixed entitlement to a resource. Water rights in spate irrigation are described as “reactive water rights” since they describe agreed claims and acceptable practices in a changing and variable environment (Lawrence and van Steenbergen, 2005). The rules for water distribution enable farmers to be surer of irrigated land, which can even be prepared before cultivation with pre-flooding. In most (traditional) spate irrigation systems maintenance requires much labour for (re)constructing of the diversion works and flood channels. Willingness to contribute is also based on sharing the benefits, which is established by giving rights. The likelihood of irrigation enables people to work together and collectively contribute to the required maintenance and operation. Rights and rules are also important to adapt to changes in the wadi morphology on the medium and long term. Spate irrigation systems have to deal with increased land levels, and changed wadi courses and flood canals (Lawrence and van Steenbergen, 2005). Without clear rights and rules, chaos and conflicts can arise. Conflicts can be minimized when water rights and rules are enforced. The in codification is a formal aspect and in many traditional schemes, rules are unwritten. The governance of schemes allows making and changing of rights and rules about allocation, delivery and use. Irrigation governance can be coordinated by a specific irrigation body or by a general local administrative body.

There are several typical rules used in spate irrigation systems about the distribution of floodwater. Spate irrigation systems can differ in many ways but the essence of rights and rules can be very similar. The combination of the right and rules used in spate irrigation

[8] Changes in control points can be a cause for many conflicts between up- and downstream farmers.
[9] Usefulness on the long term: flexibility to adapt to changes in the riverbed and the durability of structures.

systems can be heterogeneous and inequitable or relatively homogenous and equitable (Steenbergen cited in Lackner and Vincent, (1998). In the guidelines of Community Spate Irrigation by Lawrence and van Steenbergen, (2005) the following repertoire of water distribution rules are used;

A Demarcation of land entitled to irrigation
This rule precedes all other rules and defines the area entitled to be irrigated. It protects the prior right of water users against changes of river courses and flood breaches. It prohibits new land development upstream and thus new diversions of flood water in order to not affect the downstream users. This can be a serious issue especially for areas with relatively new irrigation development. With the demarcation of outer boundaries overspill from breaches can be settled to avoid drainage losses.

B Rules on breaking diversion bunds
The breaking of bunds interrupts the inundation impounded between bunds. Water is released when a certain depth has been reached or a certain time has elapsed. These time-slots are based on agreements between farmers. Not everybody is allowed to breach bunds. So also the terms on when breaching is allowed and by who are considered.

C Proportion of the flow going to different flood channels and fields
The distribution of water between different channels and the allocation is arranged within this settlement. Agreement can be made about the proportional division and or rotational distribution of water. In traditional systems crude hydraulic structures are mostly used. Discharges of flows can be adjusted by adjusting the width or blocking certain structures.

D Sequence in which the different fields along a flood channel are watered
Rights and rules about the sequence of the flood ensure entitled irrigation to certain plots, priority is given to certain main and branch canals. Also the order in which irrigation will take place can be considered. Based on the size of the flood the sequence can be adapted which allows priority to either up-, mid- or downstream users. In this way priority channels can flow if a flood is small.

E The depth of irrigation that each field is to receive
In many spate irrigation systems with field to field water distribution, the depth is used to assure a certain amount of water is impounded. The depth for irrigation can vary and is based on the height of the field bund and the levelling of the fields. The irrigation depth is according to the size of the fields and the amount of flood events in order to impound a certain amount of flood water.

F Practices regarding second and third water turns
This rule allows fields to be irrigated more than once. The amount of irrigation terms can have a significant impact on the yields. Regarding the location of the water users within the scheme, repeat applications can be a dilemma and rules vary. Difference in priority of irrigation can be made for certain special crops. Another aspect is the size of the floods, which can make it hard to reach downstream users. Finally the size of the command area significantly influences the likelihood to receive a second turn.

G Rules on small and big floods
Different priorities on the distribution of varying floods to water users up-, mid- and downstream can be established. This allows the floods to be used efficiently like for small floods, which can not even reach downstream.

Additional rules that regulate changes in the command area and system morphology:
- *Rules on maintenance of bunds and boundaries*
- *Rules on adjusting the location of intakes and other structures*
- *Rules on manipulating wadi bed and flood canal scour and siltation processes*
- *Compensation for lost land.*

Rights and rules apply only, when they are enforced. Codifying water rights and rules in documents can serve as basis for clarifying disagreements (Haile et al, 2005). In Yemen an institutional vacuum after the reunification of South and North in 1990, showed more conflicts between up and downstream users Al-Eryani & Haddas in Lawrence and van Steenbergen, (2005). The enforcement of rights and rules can decline but the rights and rules become worthless without enforcement by local leaders, organisations or government institutes.

2.5 Operation and maintenance

Spate Irrigation systems have diverse management arrangements. The management can be completely controlled by the farmers. Another possibility is joint management, where the farmers are assisted by outside agencies, like government agencies or NGO's. Finally, schemes can be agency managed, which is sometimes used in schemes after large public investments. According to Lawrence and van Steenbergen (2005) the government is becoming more important to mediate in disputes and oversee operation and management for larger systems. Spate irrigation goes along with extremes of either zero or the maximum discharge, this is different from perennial irrigation schemes, which operates within a fairly narrow range. In many spate systems the area prepared for irrigation, is larger than can be irrigated in an average year. Steenbergen (1997) has shown how in some cases many diversion structures are extended along a wadi to divert all available water, but the probability for land to receive water depends on the location and the level of the fields. The nature of the spate flood made farmers create and use infrastructure to directly divert the floods to the fields for irrigation. In the sometimes short periods that spate floods occur, irrigation needs to be carried out quickly. If systems are greater in size, it becomes more difficult to organise operation and maintenance. The organisation needs to deal with how to assure irrigation, how to organise the maintenance activities and the required means and how to operate the system and assure certain equity. According to Haile et al, (2005) the water rights and rules, the organisation and the maintenance tasks are linked. The first rule of demarcation gives clearness and recognition to water users, as being included for contributing to the maintenance and receiving floodwater[10]. This gives reasons to join collectively and contribute to the maintenance, because the right to access and use floodwater is tantamount to formalising one's contribution to the maintenance. In order to be able to supply sufficient labour and materials, everybody is required to contribute and thus to co-operate. This results in interdependence between up and downstream users and forces equity (more or less) in sharing the floods. This shows how the functioning of (traditional) spate irrigation systems is dependent on the input of its water users to maintain and operate the system properly. A major disadvantage of spate irrigation is the amount of labour and input required. The (traditional) system will only function if farmers contribute collectively. Haile et al (2005:10) stated "The key for enforcement of the water rights and rules during the indigenous system was the critical mass – the need for a large number of farmers that would work on collective maintenance". Lawrence and van Steenbergen (2005:88) mention some threats which undermine the participation of farmers to contribute collectively;

[10] The uncertainty for actually receiving floodwater remains.

- *The decline of traditional and modern government as the rule enforcing mechanism*
- *The confusion of responsibilities related to system management after public investment in the system*
- *The decline in spate systems with increased use of groundwater*
- *The changed opportunities with the introduction of mechanised power.*

The threats related to the participation of farmers can be explained. The willingness or motivation of farmers to take part of collective maintenance can be undermined. According to Al-Eryani & Haddas in Lawrence and van Steenbergen (2005), after a decline in enforcement in Yemen there were more disputes between up and downstream farmers. The likelihood to receive irrigation was decreased. Another threat mentioned, is the confusion of responsibilities due to unclear management. Without straightforward enforcement the motivation and likelihood of receiving irrigation decreases, which has its impact on the participation as well. The last two threats mentioned show external influences, making farmers less dependent on the collective action and means needed for spate irrigation. With the introduction of new technology farmers have new opportunities, but also the performance of several spate irrigation systems has been modernised. Engineering interventions were designed to improve diversion structures and to reduce or eliminate the frequent reconstruction and repair of intakes and diversion structures (Lawrence and van Steenbergen, 2005). In many aspects, expected results were not achieved. Outcomes of projects gave results such as; increased irrigated areas not realised, more inequity between up and downstream farmers, command problems due to high rates of sediment deposits and underestimated levels of operation and maintenance. Haile et al (2005) explain how in Eritrea many systems, due to the modernisation of indigenous structures and the mechanisation of the maintenance, had diminished the significance of the critical mass. Where the traditional systems require labour and collection of brushwood, the modern structures require earth moving machinery like loaders, bulldozers and trucks. According to Haile et al (2005) these changes call for different organisations with technical and financial management. Nowadays organisations need to deal with issues such like a lack of skilled people for operating the gates and working with heavy machinery. Also financial matters, since organisations have issues with the collection of contribution fees or water fees to cover the cost of heavy maintenance, repair and construction work.

2.6 Conclusion

This chapter has made clear that spate irrigation systems can vary in many different ways and that spate irrigation is complex to manage. In the framework of Mollinga (2003) the irrigation system is placed in an interrelated context, it needs to deal and fit within this context to make it work. It is not only a matter of good design and technology, also the water users need to be organised to manage the system for proper operation and maintenance. Systems can be improved or modernised but this requires also adaptation of water management. The organisation is challenged with new issues and needs to be capacitated to fulfil the requirements. The Dodota irrigation scheme is the first large-scale system developed in Ethiopia and will also need to deal with issues such as how to organise, manage and operate and maintain the system. In the new irrigation system, setting up of rules and organising principles are still ongoing processes of the government and farmers to establish structures, rules and institutions. These are linked to the context in which the system is placed according to the framework of Mollinga. The next chapter will start to give a description of the context to understand these core dynamic linkages.

3 THE CONTEXT OF THE DODOTA IRRIGATION SCHEME

This chapter gives a description of the context in which the irrigation system is placed as shown in the framework of Mollinga (2003). The first section documents the agro-ecological and technical infrastructural context. Here the climate and environment of the area made it hard for many farmers to sustain a living. In section two is the agrarian structure explained, to see how farmers survive with support of the government and were given food aid for more than 25 years. Section 3 gives an overview of the state and institutions of civil society, to see how farmers are supported by the state and extension services, to help and train them and recently by the implementation of the new irrigation scheme.

3.1 Agro-ecological and technical infrastructure

3.1.1 Geographical and ecological features

The exact location of the irrigation scheme stretches from 8° North of the equator to 11° North latitude of the equator to 39° East longitudes. The Dodota irrigation scheme is situated in the eastern highlands shown in Figure 3.1.The area is largely formed of the rocks of the Nazret group, which are made up of volcanic rocks composed of ash flow tuffs; ignimbrites and welded tuffs. The riverbed of the intermittent stream is formed of hard welded tuff and is impervious. In the south, the Boru river has its source from the Galma range of the Arsi massive at an altitude of around 4000m. This mountainous area has topographic features of a rugged and dissected river valley with many gullies and hilltops. The total catchment area is around 50km^2. Here the land cover consists of bare land except for some homestead eucalyptus trees and some indigenous acacia species. With the high slopes and bare land cover, accumulated runoff is rapidly distributed and collected along its river course. This makes the floods arrive promptly after every short rainfall but also last for a short time, which makes water management a challenge. Besides the river course, 6 drainage streams are flowing through the highlands and the command area. Also here the minimal landcover of the watershed with highland bushes, scattered trees of *podocurpus*, *juniperus* and *hyginia* does not delay the drainage streams. The streams can deliver huge discharges up to 400m^3/s with high sediment loads. Therefore additional structures have been designed to avoid side erosion and to cross the main canal, which is discussed in §4.1.2.

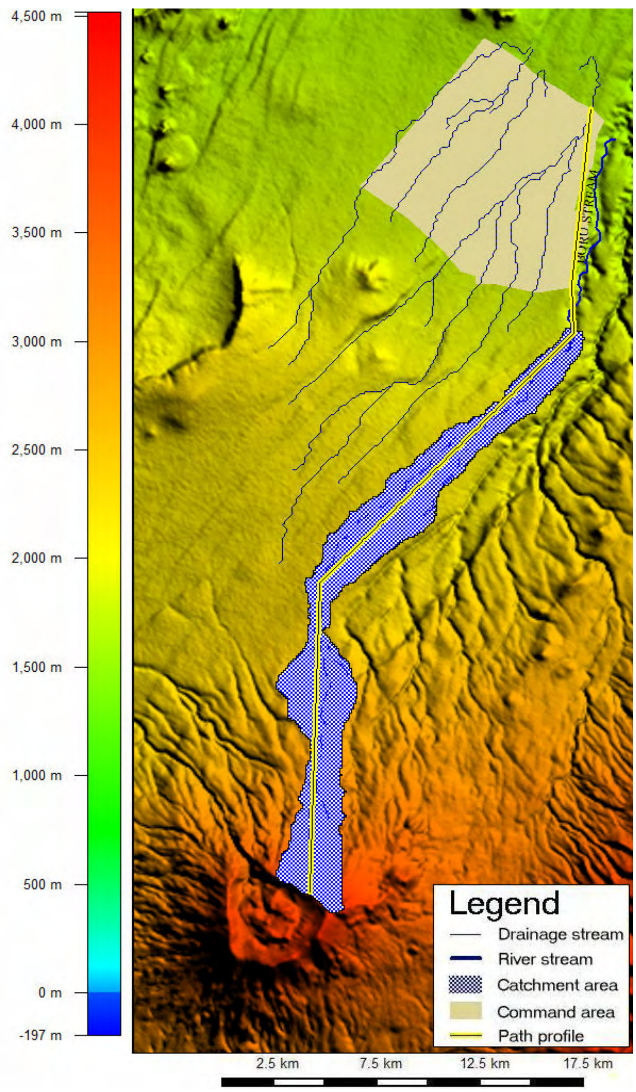


Figure 3.1: Overview of the watershed (Global Mapper)

In Figure 3.1 a path profile is shown from the highest point in the catchment area, up to the end of the command area, crossing the Boru river and passing the headworks. Figure 3.2 shows the elevation and the distances from the origin of the Boru river to the actual command area, the yellow points are a change in direction of the path. The river slope changes along its course, in the highlands the slope is rather steep, but has an overall average slope of 4% (Aman et al, 2006). Figure 3.2 also shows the gentle slope from the headworks up to the end of the command area. In the next paragraph this will be shown even more clearly and the implications this has for the design. Furthermore the Boru stream follows a southwest direction until it reaches the diversion site at 1840m, after approximately 35km from its origin. Here an important issue for the design was the sedimentation load carried by the river, a characteristic of spate flows described in §2.2. The field observation along the course of the river indicated only small course material and silt carried by the river. The design has been adapted to this as will be shown in §4.1.2.

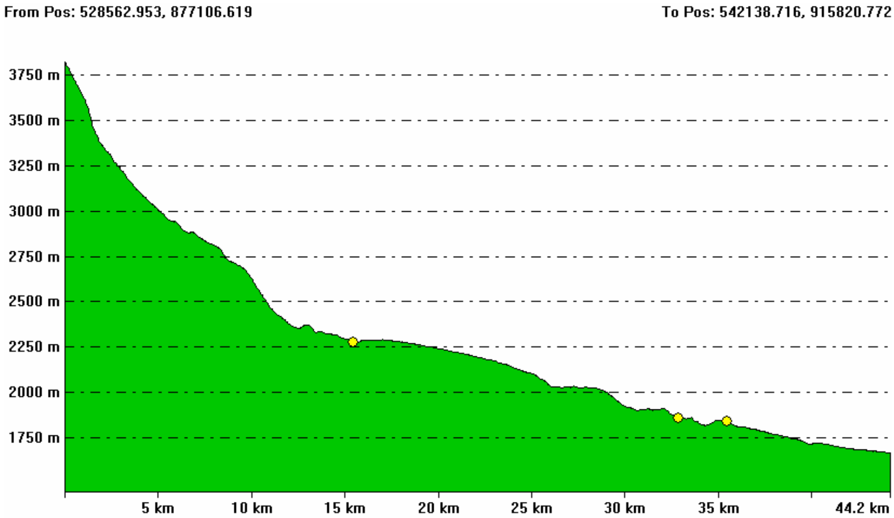


Figure 3.2: Path profile from catchment area and the command area. (Global Mapper)

3.1.2 Description of the command area

In the command area different land forms exist; flat lands, with low and gentle slopes and plain lands with a low to moderate slope. The district Lode-Hetosa is mainly midland and highland, while Dodota- Sire consists for more than 60% of lowlands. Also hill tops and rugged areas are present and divide the plains. According to a study and design team, 75% of the area is assumed to be flat (Aman et al, 2006). The difference in slope and elevation makes the alignment of canals complicated and more expensive, if additional structures are required. This will be explained elaborately in §4.1.1. In Figure 3.3 a clear model of the landscape together with the design of the irrigation scheme is shown in (main canal and branch canals) based on a digital elevation map, processed with the software Global Mapper V7.04).

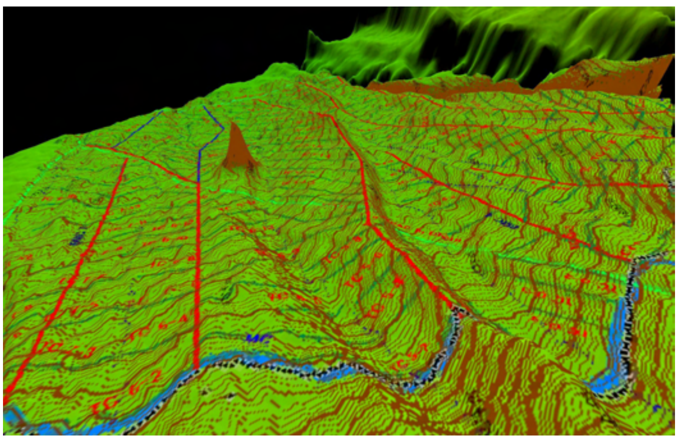


Figure 3.3: Landscape command area together with the irrigation scheme (Global Mapper)

3.1.3 Description of the soil types

The region is made of volcanic rock with ashy soils, called deposit-pumice present in the area. They are formed from volcanic ejecta (ash cinder, pumice, or some basalt). Some characteristics of these soils are; the light brown and grey colour and the high macro porosity and low texture strength (Aman et al, 2006). These soils are highly porous and erosion sensitive and therefore were also important for the design, discussed in §4.1.2. Within the command area three kinds of different soil types can be distinguished; sandy loam, sandy clay and ashy soil. The characteristics have been determined by irrigation engineers, they carried out this field study[11] in the command area. The following field specific soil characteristics have been determined by their field measurements (Kebebew and Mengistu, 2007);

- Silty clay loam texture (17.1% sand, 39.9% clay and 43.0% silt)
- The average bulk density of the top 60 cm soil depth is 1.26 g/ cm^3.
- The PH value in the sampled area is 7.64.
- The infiltration rate (double ring method) is 33.33 mm/hr

It turned out that the soils are amongst the most productive soils, with an average to low water holding capacity and average to high infiltration rate. These characteristics are most interesting for irrigation practices and conservation measures for field management and will be discussed in §5.4.

3.1.4 Meteological features

Climatic data has been collected for the command area and the catchment area shown in Table 3.1. For the command area, climatic data about the precipitation, temperature, humidity, wind speed, sunshine hours and evaporation is collected by the Wonji – Shoa Station. For the catchment area, weather data are retrieved over a period of 15 years from FAO CROPWAT of the Asela Station[12].

Table 3.1: Weather data of the command area and catchment area (2006)

Area	Command area								Catchment area		
Months	Min. T (C˚)	Max. T (C˚)	Humi. (%)	Wind S. (km/day)	S. Shine (hrs/day)	Rainfall (mm/Month)	Eff. Rainfall (mm/Month)	ET0 (mm/day)	Rainfall (mm/Month)	Eff. Rainfall (mm/Month)	ET0 (mm/day)
Jan	11,5	26,3	62	69	8,7	9	8,9	3,6	30	29	3,5
Feb	13,1	27,3	60	60	8,9	23	22,2	4	55	50	3,7
Mar	4,8	28,9	57	60	8,7	42	39,2	4,3	102	85	3,8
Apr	15,3	29	62	52	8,8	59	53,4	4,4	107	89	3,9
May	15,5	30	60	52	8,6	47	43,5	4,3	116	94	3,6
Jun	16,7	29,2	60	69	8,5	78	68,3	4,3	147	112	3,4
Jul	16,5	28	66	65	8,1	192	133	3,8	238	147	2,8
Aug	16,1	26,1	74	60	7,1	192	133	3,8	245	149	2,9
Sep	15,4	26,8	74	43	6,9	97	81,9	3,7	171	124	2,9
Oct	12	27,2	63	52	8,5	48	44,3	3,9	61	55	3,4
Nov	11	26,3	62	60	9,5	9	8,9	3,8	20	19	3,5
Dec	10,8	25,6	63	52	8,4	8	7,9	3,3	6	6	3,3
Total					100,7	804	644,4	47,2	1298	959	40,7
Mean	13	28	64	58	8	67	54	4	108	80	3

In the command area, the altitude, temperature, and rainfall vary and result in different climatic distributions for highland, midland and lowland areas. Caldwell in Teschome (2003:23) described three agro-ecological zones: the *dega* (highlands) at an altitude of 2300 meters and more, characterized with cool temperatures; the *weyna dega* (midlands) with an elevation of 1500 to 2300 meters and a moderate temperature; the *kolla* (lowlands) between 500 and 1500 meters with warm temperatures. The agro climatic classification of the project area is at the border of tropical-humid: altitudinally it is located at a height of 1300 to 1800 meters with an average of 1500 meters.

[11] Soil samples were taken from several locations in the command area (locations are not specified here).
[12] Asela has a weather station and is located 30 km from the project site.

In Ethiopia there are two main seasons, *keremt* (wet), *bega* (dry) and there is a differentiation of a third period, *belg* (minor season). The *keremt* season lasts from June to September and the *bega* season from September to April. The third period is referred to as a minor season, The *belg* rainfall season usually begins in January-February and ends in April-May. In the project area, the rainfall conditions are considered bi-modal because it has both rainfall seasons (*keremt* and *belg*) and thus the area has a long rainfall season. However in the command area the rainy season lasts for only three months, from June to August. Rarely the first days of September have some days with minimum rainfall. The summer is hot, dry and windy. The catchment area from the Boru river has the long rainfall season from mid of February to October. From November to January there is little rainfall, after that period it increases. The rainfall data[13] in Table 3.1 is depicted in Figure 3.4 and clearly shows the difference between the catchment- and the command area, in duration and amount of rainfall.

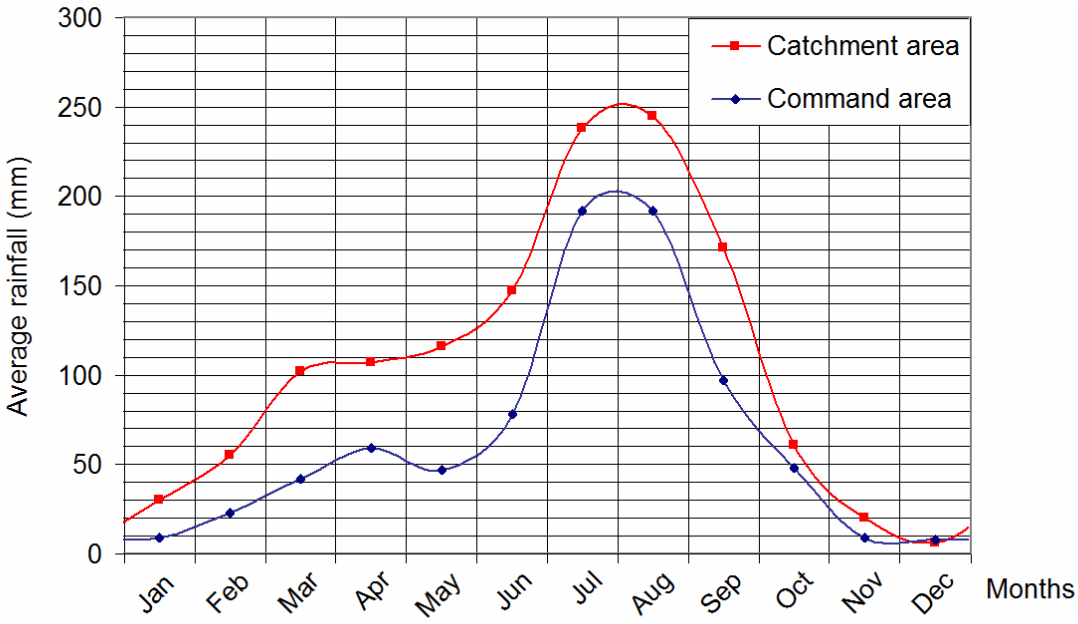


Figure 3.4: Average rainfall distribution in the catchment- and the command area (2006)

The rainfall season in the catchment area has more rainfall and also lasts longer. In the command area, the annual rainfall varies between 450 – 850 mm but has an erratic and unreliable nature. This limits the production of farmers and gives the chronic need to food aid.

3.1.5 Hydrological features

The semi-perennial Boru river supplies the Dodota scheme. The stream has no other off-takes upstream along and is not used by other upstream or downstream users; designers have assumed this allows the stream to be completely diverted, even if it has a very low discharge. One of the difficulties for the design, was estimating the discharge of the Boru River and the drainage streams, running through the command area. The stream of the river had never been measured, which made it necessary to make an estimation of the peak discharge, in order to be able to come up with an appropriate design. Several methods were used to estimate the peak discharge; slope area; basin approach; rainfall frequency analysis; MAF method; and the complex hydrograph method (Aman et al, 2006). The outcomes of these methods were calculated and vary, but have also been compared with simple field analyses, such as; field observations like flood marks and local farmer interviews. Finally the area-slope method was selected as the most accurate. The differences between the calculated estimations and the area-slope method were more than twice in case of the basin approach, which comes up with a

[13] Used here, average rainfall, data was insufficient to determine the 80% dependable rain.

peak flow of 211 m^3/s. Nevertheless the design had been adapted to the estimated peak discharge of $100 m^3/s$. For the estimation of the drainage canals only farmers' knowledge and flood marks have been used. With the determination of the cross sectional (A) areas and the use of the formula Q=A * V[14], the different drainage canals have been determined, these are given in Table 3.2. The discharges can be high, but has a short duration. To deal with the drainage, additional structures have been designed, discussed in §4.1.2.

Table 3.2: Discharges of drainage canals in the Dodota irrigation scheme

Name of drainage	Anko	Ademere	Badossa	Bika	Genjo	Dodota
Discharge m^3/s	20	30	400	110	70	40
Average flowing days	2hr	3hr	6hr	1 day	8hr	1hr

The peak flow of the river was estimated roughly: also the total water availability which can be used for irrigation is unclear. The semi-perennial river is completely dependent on rainfall with also high daily rains indicated in APPENDIX 1, in the catchment area. In Figure 3.5 estimations are shown of the discharge of the Boru river based on farmer's knowledge and a Fsimple rainfall calculation. A preliminary estimation can be simply made by using the rainfall data of the catchment area from Figure 3.4. Based on this information a continuous flow is calculated.

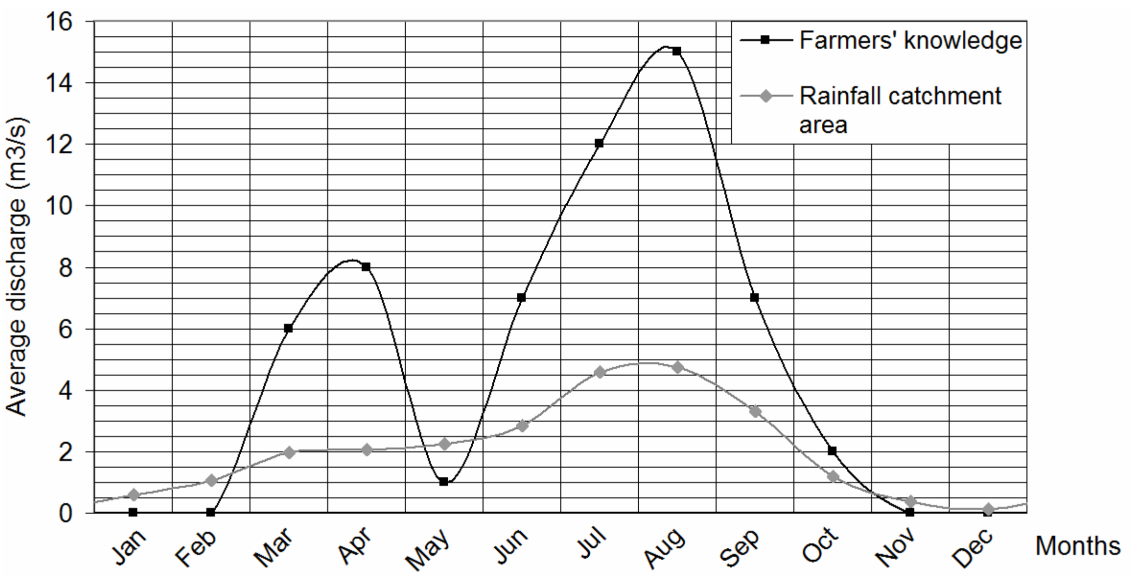


Figure 3.5: Average Boru stream discharge, based on different inputs

It appears that before losses such as, percolation, evaporation and transpiration are considered, a total continuous flow of 4,7 m^3/s in August can be received. This is three times lower than the expectation of the farmers in that month, but on average it is likely to be even lower also due to variable peak rainfall. Thus it is already clear that the system cannot continuously run on its maximum capacity because the floods can vary tremendously over time, which will make the use and share of the available water highly complex to manage. The flood stream has also implications for the design of the spate irrigation system. The design of the diversion weir at the head of the system needed to be adapted to the peak flows and low discharges. It also required adaptation to deal with the sedimentation. Furthermore, it needed structures to divert and allocate the water to its water users to irrigate their fields. More aspects about the design and operation and management will be discussed in chapter 4.

[14] Manning formula $Q = 1/n\ R^{2/3} S^{1/2}\ A$ in which :
Q =discharge (m^3/s); n =Manning's roughness factor ($m^{-1/3}.s$); R = hydraulic radius R = A/P (m);
S = energy gradient ; A = cross-sectional area (m^2); P = wetted perimeter cross-section (m) .

3.2 Agrarian structure

The scheme is located in the Ormoyia region and the Arsi zone. The area under development, covers around 9000ha from which 5000ha is the potential irrigated area. The command area is situated in 2 districts or w*oredas*, namely Dodota-Sire and Lode-Hetosa. Furthermore the project is found in 6 *kebeles* as depicted in Figure 3.6.

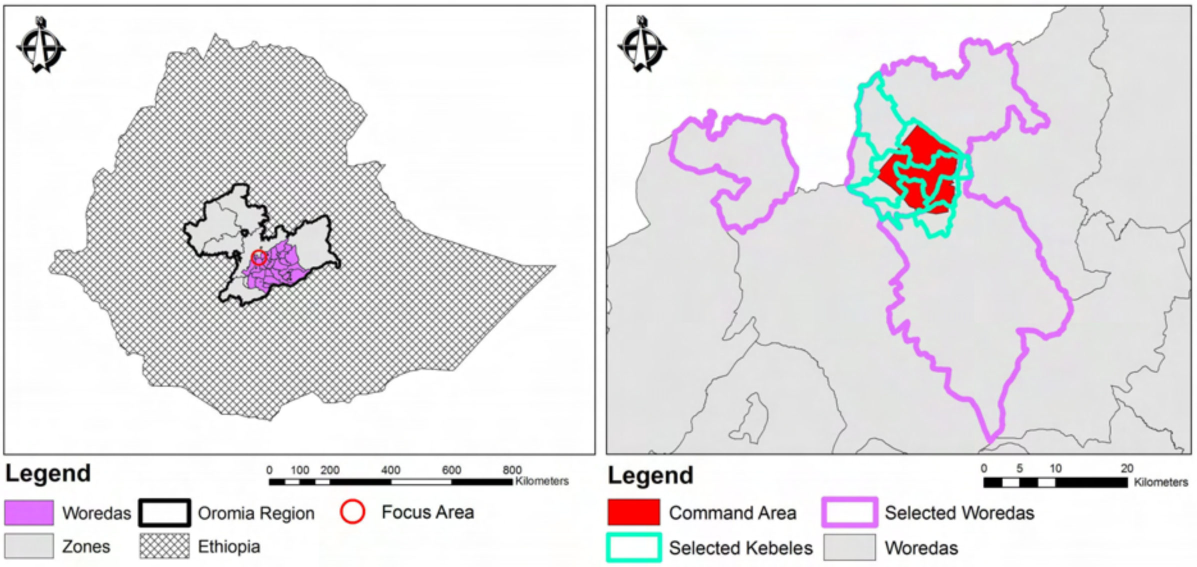


Figure 3.6: Location of the irrigation scheme (ArcGis 9.2)

The Dodota Sire district is identified as one of the 262 chronically food insecure *woredas* and covered by the Safety Net Programme, which is part of the Food Security Programme in Ethiopia. *Woredas* and households are identified as chronically food insecure if they are a recipient of food aid for a significant period[15]. According to the Productive Safety Net Programme (2006:3); "beneficiaries of the programme are resource-poor and vulnerable to shocks, and often fail to produce enough food even at times of normal rains in the country". The households participating in the programme are supported with "public works" or "direct support". Public works are described as labour intensive community-based activities, designed to provide employment for chronically food insecure people, who have "able-bodied" labour. Direct support delivers assistance to those households who cannot participate in the public works, or who are labour poor and do not have reliable support. In Dodota-Sire there are from the 26 Peasant Associations (PAs), 18 organized under the Safety Net Programme. Here out of 30750 households, 88% has the benefit through for food work and 12% has direct support (Aman et al, 2006). Support in the project area is mainly given through participation in public works. Also some preparations for irrigation were assisted, see §4.1.3. In 2006, 3799 Households with a total population of 26513 were living in the project area. Table 3.3 indicates the essence of the intervention, since on average almost 40% is dependent on the Safety Net Programme to address food self-sufficiency at household level. Many people receive food for work in the project area and it can be concluded that the program has a great impact. The dependency however does not account for all *kebele*, in Melka Jebbi food aid is not required, this will be explained later on in this paragraph.

Table 3.3: Population and food aid given in the *kebeles* (WRDO, 2007)

District	Dodota- Sire										Lode-Hetosa	
Kebeles	Amigna Debaso		Teducha Guracha		Dodota Alem		Dilfkar		Sharbe		Melka Jebbi	
Total Population	4828		5774		4979		4196		2660		4076	
Households	580		566		863		515		412		863	
Average size	8		10		6		8		7		5	
Number of people receiving food aid	1.237	25,6%	3.028	52,4%	3.321	66,7%	1.753	41,8%	778	29,2%	0	0%

[15] Generally this period must be at least three years but in Dodota-Sire it is already for more than 25 years.

The majority of the population in the project area are ethnic Oromia and are speaking the language of “Afan Oromo”. The main religions are Orthodox Christianity and Islam. The area is recognizable by poor farmers of which many are depending on food aid and poorly developed social services and infrastructure. In the project area there are small villages where only a few social services can be found. Every *kebele* has a health post, elementary school and almost all *kebeles* have access to drinking water from a hand dug well. Within the villages, no water supply system or connection to an electrical power net is established. Most services can be found in the surrounding of local towns. In case of further education, students can go to Huruta and Dhera. In Nazret, students can join the university and a hospital is located there. Recently the access to services in local towns and Nazret has been improved tremendously by the construction of an asphalt road, not more than 2 years ago by the Ethiopian government. Also the development and construction of the irrigation scheme, with infrastructure like roads and bridges within the project area will contribute to improve the current situation. At this moment, the project area is hard to reach and not connected to other cities by a main road. The construction of the main road will increase the accessibility to markets and social services significantly. The project area is near Nazret at 40 km distance which is the third largest city in Ethiopia. Around the project area 2 markets can be found, in the small village of Dhera at approximately 15 km and in Huruta town at 10 km distance. With developed infrastructure these markets are accessible which could boost the local economy.

In the project area agriculture is the main economic activity and farmers practise both crop and animal husbandry for their livelihood and income generation. The landholding size has not changed since the land reform in 1975. At that time the land was divided based on family size. Currently the average land size in the project area owned by families is about 2 Ha according to (Aman et al, 2006). New emerging families can get cultivable land through share cropping, on rental basis or from their parents, see §4.2.2. Until the introduction of the new system exclusively rainfed agriculture was practised. The major crops in the project area were; wheat, barley, teff, linseed and haricot beans (Aman et al, 2006). With the new scheme it might be possible for farmers to grow other crops and a second crop instead of producing a single crop only. With the irrigation scheme plots will have access to supplemental irrigation and therefore will also increase in value. Since the production is used for home consumption and for sale at the local markets, more profit can be made with increased production. The changes in cropping patterns and traditional farming methods will be illustrated in §5.2. Another activity is animal husbandry and animal production, which is used for food consumption, milking, traction power, for transportation and other necessities. With the generated income social needs such as education, medical care, clothing and others needs can be covered. The weak economic status of farmers makes it difficult to acquire inputs like seeds and fertilizer for the prevailing market prices. This makes it also more difficult to intensify production.

Farmers are organised based on the government structure of the Peasant Associations. These administrative offices collect data from the farmers and support the farmers, see §3.3.1. The data obtained from the Agriculture Rural Development Office of the different *kebeles* within the irrigated area can give some insight in the current local socio-economic situation, this is revealed in Table 3.4. Since the project area is only a small part of the districts, district-level data is not relevant to use here.

Table 3.4 : Landuse in the *kebeles*, sept. 2006 (ARDO)

District	Dodota- Sire										Lode-Hetosa	
Kebeles	Amigna Debaso		Teducha Guracha		Dodota Alem		Dilfkar		Sharbe		Melka Jebbi	
Landuse	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Cultivated	2324	86,7%	3136	98,0%	2535	87,2%	2576	91,2%	2282	99,9%	1679	77,8%
Grazing area	15	0,6%	44	1,4%	276	9,5%	200	7,1%	0	0,0%	300	13,9%
Forest area	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%	40	1,9%
Construction & others	341	12,7%	20	0,6%	97	3,3%	50	1,8%	0	0,1%	140	6,5%

In relation to the land use of the different *kebeles*, some economic activities can be distinguished. Depending on the climatic zones, the production based on rainfed agriculture can be locally different. For this reason some farmers can be food self-sufficient, while others cannot. From the data in Table 3.3 and from field visits in Melka Jebbi, it became clear that they can produce enough food with rainfed agriculture. It appears that the rainfall distribution is better since they are situated at a higher altitude upstream to the Boru river. Table 3.4 shows that Melka Jebbi has relatively the smallest cultivated area representing 77,8% of the land use and at the same time the largest grazing area with 13,9% of the land use. All other *kebeles* have much more cultivated area up to 99.9% in Sharbe. Other land use is mostly grazing area or land used for construction. Overall the figures in Table 3.4 show that even though there are some differences in land use, people are heavily dependent on agriculture. In other spate areas due to the drought periods and erratic rainfall it is seen that people try to overcome bad times with investments in livestock (Lawrence and van Steenbergen, 2005). If farmers have a better financial status, investment in cattle can be afforded. In this way, it is also interesting to see the livestock according to *kebele* and thus to see the differences according to their economic status as shown in Table 3.5. The ratio shows the relation between the amount of people and the amount of livestock. Especially cattle are important and used for traction and land preparation. In Melka Jebbi with a ratio of 39.7%, almost two out of 5 people have cattle in that *kebele*. Amigna Debaso has the lowest ratio of 8.6%, here land preparation could be an issue. But in interviews farmers explained there were sufficient cattle to prepare their lands and otherwise cattle were rented. Another important indicator is the amount of donkeys, used for transportation. From this it becomes clear that in Melka Jebbi and Sharbe a lot of farmers have donkeys with 16,7% and 16,5% respectively, which are mostly used for transportation to the nearby market in Rhuta.

Table 3.5: Livestock in the *kebels,* sept 2006 (ARDO)

District	Dodota- Sire										Lode-Hetosa	
Kebeles	Amigna Debaso		Teducha Guracha		Dodota Alem		Dilfkar		Sharbe		Melka Jebbi	
Livestock holding		Ratio		Ratio		Ratio		Ratio		Ratio		Ratio
Cattle	415	8,6%	1248	21,6%	1475	29,6%	845	20,1%	935	35,2%	1619	39,7%
Sheep	1408	29,2%	697	12,1%	645	13,0%	597	14,2%	520	19,5%	600	14,7%
Goat	106	2,2%	473	8,2%	556	11,2%	501	11,9%	300	11,3%	460	11,3%
Poultry	809	16,8%	1025	17,8%	2135	42,9%	1622	38,7%	1600	60,2%	400	9,8%
Horse	40	0,8%	13	0,2%	30	0,6%	7	0,2%	20	0,8%	20	0,5%
Donkey	450	9,3%	311	5,4%	403	8,1%	210	5,0%	440	16,5%	680	16,7%
Mule	1	0,0%		0,0%		0,0%	11	0,3%		0,0%		0,0%

It appears that there are some differences based on socio-economic figures according to the location of the *kebeles*. There are differences in the need of food aid and the economic status related to agricultural production and market access. The local development of the irrigation scheme and the infrastructure could therefore make a huge difference. Hereby the importance of the agrarian structure must not be overlooked. According to the framework of Mollinga (2003) farmers adapt to the agro-ecology. As seen in practice, farmers could barely make a living and are dependent on food aid instead. The irrigation technology could make a difference to overcome the erratic and unreliable rainfall. But this change will not come by itself, especially not since the poor developed status of the farmers. The role of the state and institutions of civil society is to involve, support and guide farmers to deal with their environment in order to survive and make a living. Their role is also related to the introduction of new technology and therefore changing.

3.3 State and institutions of civil society

In the framework of Mollinga (2003) the state and institutions of civil society[16] are part of the context. These structures can be; government agencies, NGO's, social movements and education and training institutions. For the study, the government institutions, the institutions involved for the establishment of the Safety Net Programme and the irrigation sector were important. The lateral focuses on the newly introduced Dodota irrigation scheme and the structures which are involved in transforming the livelihood of farmers.

3.3.1 Government structures

The government is institutionalised according to the Oromia Regional State Administrative structure and has a four tier organizational set-up. First there are the regional level bureaus or federal state bureaus, and then there are the zonal level offices, followed by the district level *(woreda)* offices and the Peasant Associations (PA). The *kebele* is the smallest administrative unit and organised by the PAs. For the case study most information was collected from the district office and the PAs through secondary data and interviews. At district level the Agriculture Rural development Office is engaged in the guidance and supervision of extension services within the *woreda*. Here there are so called Development Agents (DAs) placed as frontline workers in day-to-day contact with farmers in the different PAs. These administration offices collect information and based on their progress reports and evaluations the *kebeles* are supervised. The *kebeles* themselves are governed through a cabinet with 7 different posts concerning; the agriculture manager, education representative, health representative, village leader, deputy manager, security head and the development agent. The agricultural manager is the leader of the post regarding the farmers, livestock agriculture and natural resources. The farmer representatives of different PAs report directly to five people, and they in their turn communicate directly to another 8 persons. These last 8 persons communicate in groups to another 30-40 persons from different households. In this way the farmer representative of each peasant association is able to reach up to 1600 households. For the local management of the scheme the community needs to be involved. In the system it is the PA structure that will be used as a base for the Water User Associations (WUA), see §4.2.1.

3.3.2 Safety Net Programme

The project area is supported by the Safety Net Programme which is part of the Food Security Programme in Ethiopia. The regional and federal food security coordination offices have the responsibilities of providing directives and facilitating joint planning of food security programmes. The *woreda* Food Security Task Force has the responsibility of facilitating the integration of the SNP into *woreda* food security programmes, in close consultation with the appropriate implementing agencies involved in food security programmes. The PSNP objectives according to the Programme implementation manual (2006:1) are: "to provide transfers to the food insecure population in chronically food insecure *woredas* in a way that prevent depletion at the household level and creates assets at community level. The Programme will thus address immediate human needs while simultaneously (i) supporting the rural transformation process, (ii) preventing long-term consequences of short-term consumption shortages, (iii) encouraging households to engage in production and investment, and (iv) promoting market development by increasing household purchasing power." Public works and activities undertaken must be on community land and at the community level, but beneficiaries will not be paid to work on their own plots or assets. The outcomes of the community activities can result in: improved land productivity and soil fertility; land availability; market infrastructure; access to drinking water and irrigation; availability of

[16] Civil society structures were not involved in the transformation processes or the establishment of collective action related to farming practices or irrigation practices.

fodder and school and health facilities. Some examples of development activities of public works include; mulching of degraded areas; development of roads and bridges; stream diversion; water ponds; conservation measures; and repairing and building of classrooms and health facilities. To establish the required field preparations for this year, farmers have been given food by the SNP program in exchange for their contribution. In this sense the SNP can constitute a trigger to the community to join and participate in irrigation activities, this will be further illustrated in §4.1.4. The implementation of safety net activities is coordinated by the *woreda*, which determines the needs and undertakes the planning. Here the highest decision making body at *woreda* level, the Woreda Council is responsible for the allocation of safety net resources in line with the size of the vulnerable population and based on the recommendation of the Woreda Food Security Task Force (WFSTF). The Woreda Rural Development Office (WRDO) acts as chair of the WFSTF. The FSTF is also established at *Kebele* level (KFSTF) and at community level (CFSTF) to oversee planning and implementation of safety net activities and respectively of the identification of the beneficiaries within the community. Besides the council/cabinets and the FSTF there are several other task forces at different levels, involved in the establishment of the SNP, but only a few are mentioned here to understand the main objectives and approaches of how it is imbedded in the project area. At community level, every year there is an assessment on the basis of its identified food insecurity by the CFSTF to check if the households should stay in the programme or not. The first basic criteria for selecting beneficiaries are, households which are members of the community and who have faced continuous food shortages (3 months or more) in the last three years and received food assistance prior to the commencement of the PSNP programme. After this a further refined selection of eligible households is made, based on the status of households' assets, income from non-agricultural activities and alternative employment and the support from relatives or community. Households are targeted based on the level of their poverty but an overall goal is graduation from the SNP programme. Here the importance of the development of the irrigation scheme is evident since this could improve the assets and livelihood of households.

3.3.3 Irrigation sector

The irrigation sector has a similar organization regarding the Oromia Regional State Administrative structure and is clearly described in the operation and maintenance manual for the Dodota irrigation scheme by Derese (2008). Four levels can be distinguished, the Ministry of Water Resources (MoWR) can be considered the fourth tier since it is responsible for the development and management of water resources[17] of the whole country at federal level. It formulates policies for the water sector. It is involved in the long term planning strategies, setting of standards and the coordination of projects and funding and cooperates with foreign donor agencies. It provides technical assistance and advice to the regional governments.

The regional Water Resources Bureaus (WRB) and the Bureau of Agricultural and Rural Development (BARD) operate at regional level and are responsible for the study, design and integrated development and management of medium and large scale system. At zonal level, the Water Resources Development (WRD) and the BARD are responsible for carrying out; integrating watershed management & conservation measures; all promotion activities and undertaking studies related to agricultural development; irrigation development; providing agricultural research; and extension services and promoting the establishment of farmers' cooperative associations. Responsibilities and activities of the BARD are described more in detail in APPENDIX 2.

[17] This includes large-scale irrigation development.

At district level the Agricultural and Rural Development Offices (ARDO) are involved in the study, design and development of irrigation and they support the farmers with the operation, maintenance and management of the system. Here the Cooperative Promotion Commission Bureau (CPCB) is one of the main interfaces between the BARD and the farming community. The CPCB organizes, trains and promotes the cooperatives and is involved in the establishment of the water user Cooperatives. They support the coordination by setting up bylaws and by financing and facilitating the provision of commercial services like input supplies, rural credits, marketing promotion and industrial products. To ensure proper management they are also involved in the day-to-day follow up, which they support with trainings and audits. At local level the farmers and water user associations are held responsible for the water management of the system, including the operation and maintenance and the cash collecting activities. The irrigation sector has put in place structures and processes for the operation and maintenance and water management of the scheme, to enable farmers to improve their livelihood, this is further clarified in §5.6.

3.3.4 Governmental irrigation enterprises

There are different government companies involved in the arrangement of the Dodota irrigation scheme as described by Derese (2008). Mainly three governmental enterprises have contract-client relations and contributed to this project. The Oromia Water Resource Bureau (OWRB) is a governmental enterprise involved in the regulation of water, licensing private and public operators and the design and construction of irrigation projects and has subordinate offices at zonal level and *woreda* levels. They approve soil chemical and physical properties and control and monitor developed irrigation schemes to mitigate negative effects on downstream communities and natural resources. Also they are involved in the handing over of the completed irrigation scheme to users. A more detailed description of the responsibilities and tasks of the OWRB is given in APPENDIX 2 .

The Oromia Water Works Design and Supervision Enterprise (OWWDSE) is contracted by the OWRB for design and supervision during construction, and consultancy for operation and maintenance. Another commercial enterprise working for the OWRB is the Oromia Water Works Construction Enterprise (OWWCE) which provides drilling and construction services. They have been given a new mandate from the regional state to construct, own, operate and maintain large-scale irrigation and water supply projects in the region, including the Dodota irrigation scheme. Also for the OWWCE a more detailed description is given in APPENDIX 2.

3.4 Conclusion

This chapter described the context of the new Dodota irrigation scheme according to the framework of Mollinga (2003). It has shown how the geographical and hydrological situation of the Dodota irrigation scheme is linked to design choices, infrastructure and future water management. The second aspect in the framework is the agrarian structure, which is recognized by the dependency on food aid and a poor developed status and need to be taken into account for the operation and maintenance of the system. To make proper and successful use of the new system, adaptation in land and water rights and cultivation practices of the farmers is essential. Here the state and irrigation institutions play an important role to involve the farmers in the operation and maintenance of the system and to transform the livelihood of farmers. Currently the SNP is contributing to establish the so called “critical mass”, required for irrigation activities, but since the role of the SNP is to change in the future, forms of organisation to manage the system and establish community participation is of great importance. The water management and operation and maintenance of the scheme, implemented so far and in the future, will be discussed in the next chapter.

4 THE DODOTA IRRIGATION SCHEME

The framework of Mollinga (2003) summarises all activities that take place in irrigation systems in the triangle of 'people', 'forms of organisation', 'technologies' and 'water'. This chapter studies the basic elements of the irrigation system and is structured using the irrigation management framework of Uphoff described in Pant, (2000 p.16). The first section describes the dimension of 'control structures' and clarifies the issues in the design and the infrastructure and explains which operation and maintenance activities take place. In the second section the 'organizational activities' are described and this makes clear how the system is managed and which rules and rights are applied and developed. The last chapter deals with the 'water use activities' and illustrates how water is distributed and allocated in the last irrigation trial and in the future.

4.1 Control structures

4.1.1 Irrigation design and principles

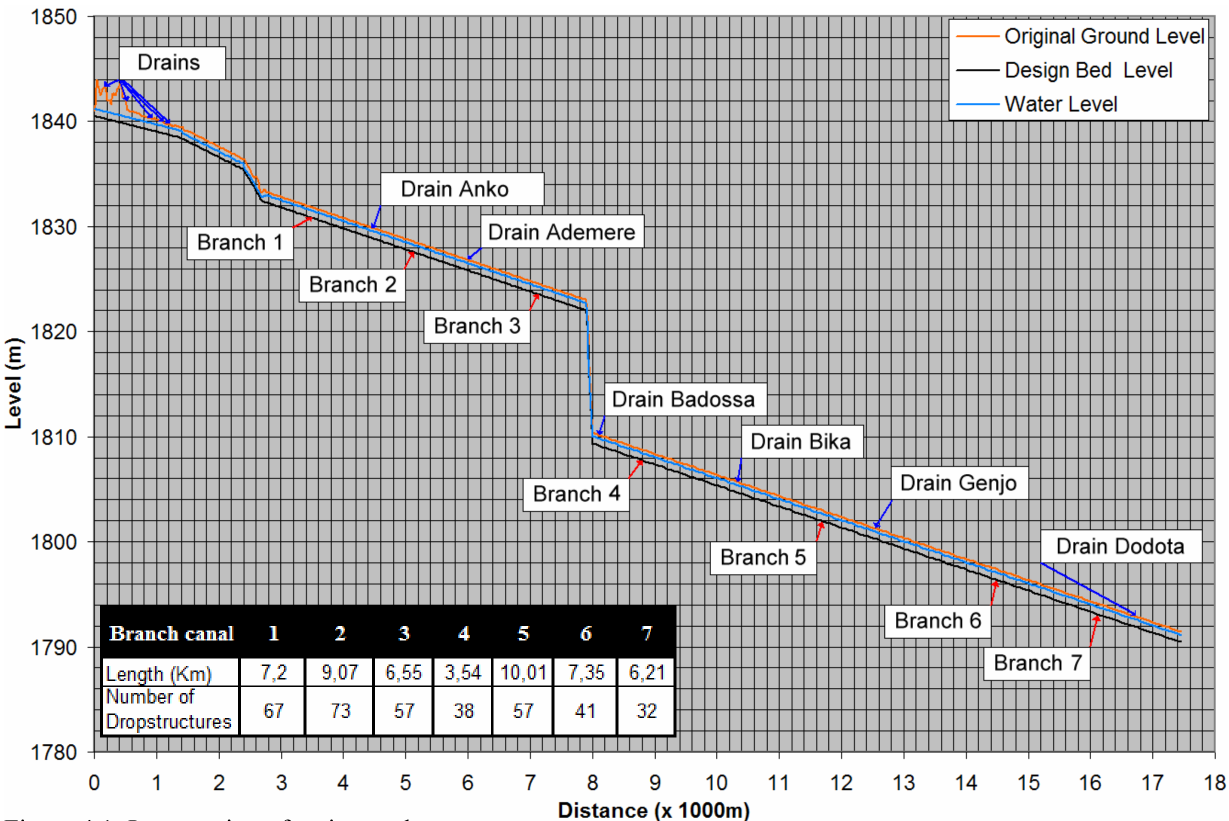
The total area considered for the new irrigation scheme covers around 9000ha. The total net potential area for spate irrigation was estimated to be approximately 5000ha. The main objective of the design was to function as supplementary irrigation and to make use of the base flow of the Boru river. The river flow is semi-perennial (4-6 months) and could be used for conventional water distribution. It was thought that with permanent infrastructure the sedimentation and water flow could be controlled and resulted in the design of the Dodota spate irrigation system. The design had to be cost-effective with simple and effective structures with a lifetime of at least 20 years (Aman et al, 2006) and allow possible future expansion[18]. Based on the requirements, permanent structures made with concrete and masonry were selected. With guidance and supervision these structures could be simply constructed by the local people and they would require less maintenance on the long run. The farmer community was only involved to contribute to the construction of the design, but they had no influence on, or participation in the design. Another striking aspect about the design process was "the parallel implementation", as the design process was continuing parallel to the construction. In this way it was difficult to make adjustments in the design and to make design choices, especially as at that time it was not even clear who was about to manage the system, or would be responsible for the system. This will be further discussed in §4.2.1.

The information available for the design was also limited and mainly based on field experiences of the local farmers. One of the main design inputs to determine the strength and dimensions of the headworks was the maximum peak discharge as discussed in §3.1.5 and estimated at $100m^3/s$. Another point of interest for the design of the system was the average base flow which could be diverted for irrigation. This was hard to estimate, since the Boru river flow varies every few hours and the peaks vary per day in time of appearance and grade. But with the support of the farmers, the base flow was determined in the same way as the peak flow and estimated to be around 10 m^3/s, with an average discharge[19] of 2.1 m^3/s. Based on the flow of the river and in line with the objectives of the project to construct a permanent small diversion weir with low cost, an ogee weir has been designed to divert 6 m^3/s to irrigate the potential command area of approximately 5000ha. The intake from the weir can vary from 0 m^3/s to 6 m^3/s up to 11 m^3/s FSL (Full supply level) including the freeboard. For spate irrigation the diversion capacity of the weir is relatively limited since spate irrigation is

[18] Options are; improving the water availability with the diversion of the Wadecha river and or the Keletta river (perennial flow) and increasing the command area by extending the main canal and or secondary branch canals.
[19] Here was considered the average rainfall in the catchment area, which would give an average annual flow.

known to divert the flood for direct irrigation as discussed in §2.2. But not only the headworks need to divert a certain capacity, but the system as a whole needs to be able to handle the stream. With a higher diversion capacity, this results in much higher costs for the construction of the canals and structures in the rest of the system. In this sense the Dodota irrigation scheme is much more conventional, because it relies on a semi-perennial flood stream instead of single flood events and requires therefore smaller canals and structures. Another point of attention besides the conventional layout with secondary channels is the water distribution to the branches. This is based on 24 hour irrigation and all the division boxes have the same dimensions, despite the command area they serve. This immediately shows that the system is not designed according to the actual command areas and also crop changes are not considered. The system is designed to realise a water duty of 1.2 l/s/ha. This appears very high but is the gross water duty, the net water duty will be much lower, which will be explained in §4.3.1.

The main canal is constructed along the contour line for a total length of 17.4 km. In Figure 4.1 a long section of the main canal is shown to see the details about the exact locations of the drains and branches and the levels of the design bed. The secondary branch canals are crossing the contour lines and are connected at different bed levels. The dimensions and trapezoidal shape of the secondary branches are similar but they have different lengths and numbers of drop structures. Additional structures have been designed to protect the main canal from erosion and drainage flows from the upper watershed. The larger drainage canals are crossed in so called “ cross level drain” structures. These structures can supply the main canal with drainage water if it is not running at full supply. It is not sure whether these will cause additional sedimentation within the supply canal, or erode the earthen canals, since the drainage water is coming from the upper watershed and can evolve as huge streams of up to 400 m^3/s as seen in §3.1.5. However these drains can increase the water availability for irrigation, if there is insufficient flow in the Boru river. Nevertheless, these structures will require additional maintenance and will have some implications for losses in the main canal.



Branch canal	1	2	3	4	5	6	7
Length (Km)	7,2	9,07	6,55	3,54	10,01	7,35	6,21
Number of Dropstructures	67	73	57	38	57	41	32

Figure 4.1: Longsection of main canal

In Figure 4.2 an overview of the scheme is given, based on the layout of the designer (Aman et al, 2006) and by driving and walking through the system. The secondary branch canals are connected to the main canal with proportional division boxes. All the division boxes have the same dimensions and distribute proportionally approximately 1m^3/s into each of the secondary channels. The design of the canals is based on an elevation model obtained by radar and combined with SRTM-7 satellite images. The topographic map with the digital elevation map with the contour lines, was the basis for the hydraulics of the design. The exact canal alignment is changed from the original design and has been adjusted and adapted by the field engineers, to specific field situations in order to avoid crossing villages or houses. Roads and footpaths which were crossed by irrigation- and drainage canals, were improved by mainly culverts and bridges. This is also seen in Figure 4.2 when the main road from Dhera to Rhuta is crossed. However not indicated are the crossings of the smaller footpaths with footbridges and farm bridges. The next paragraph deals in detail with the infrastructure, to have a better understanding of how the system is constructed.

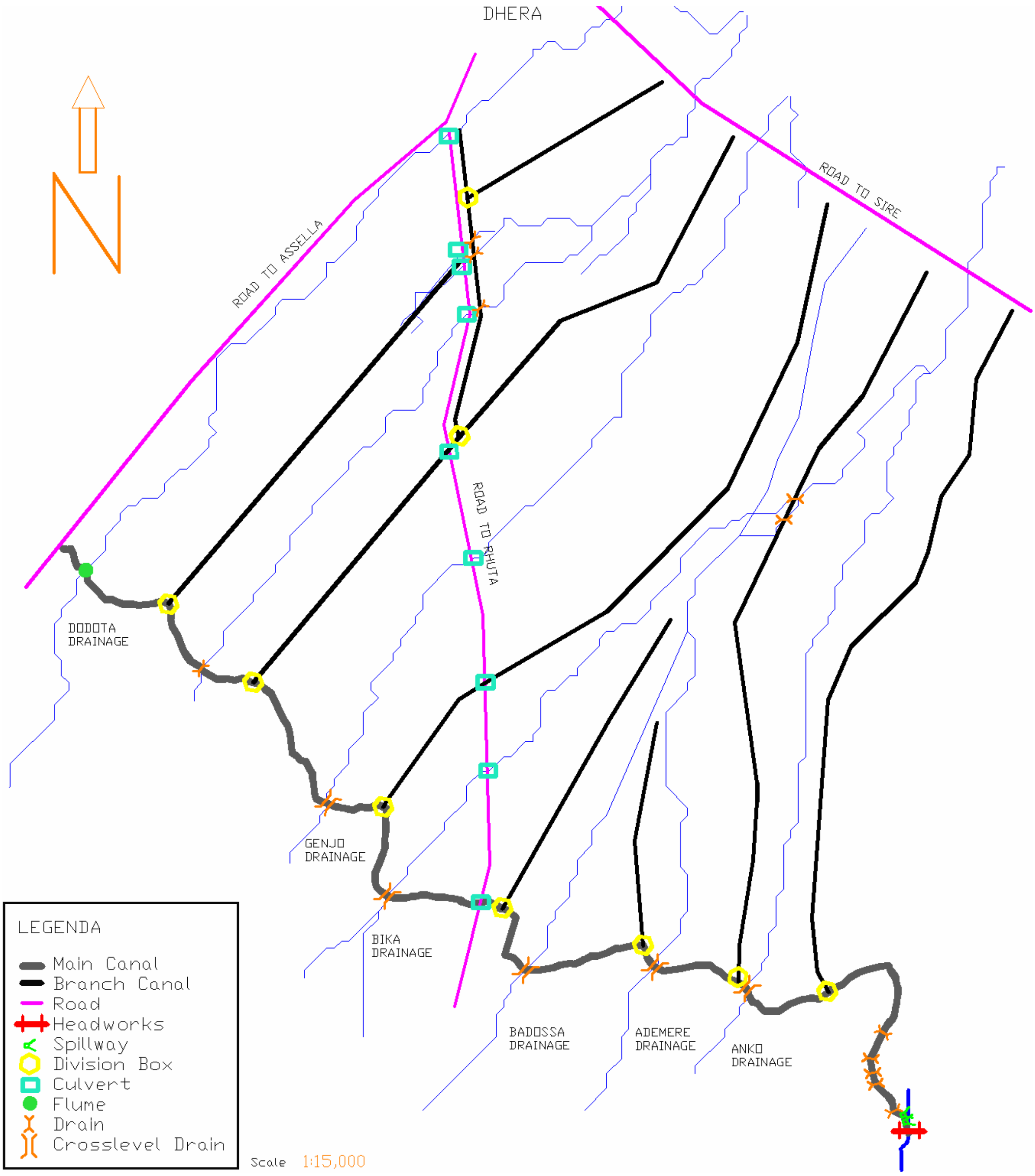


Figure 4.2: Overview of the layout of the system (AutoCAD 2007)

4.1.2 Infrastructure

The *headworks* depicted in Figure 4.3 is located at an height of 1840,5 meters. The discharge water from the wadi flows over an ogee weir of 5 meters wide. To prevent high loads of sedimentation blocking the weir, a flush gate has been installed. The intake at the weir can be flushed by this sluice gate. There is no need for trash racks, since only small stone and sedimentation can be found around the riverbed. The head work is constructed on hard bare rock. The main canal is excavated from the bare rock and is unlined, it functions as an impervious layer. Further downstream a section is lined to avoid losses.

Figure 4.3: The headworks

Near the intake an *overflow structure* is designed, to spill the abundance of water if the discharge of the wadi is excessive. The discharge through the canal is designed for an average of $6m^3/s$ up to 11 m^3/s including the free board.

The main canal is lined when the impermeable rock layer becomes porous. The main canal can be controlled by three sluice gates at the *rejection spillway* depicted in Figure 4.4. If spate flows are very large the spillway is used to reject the flood from entering the system. If there are any problems in the distribution of water, or less need of irrigation water, these sluices can be closed. The spillway is lined to protect the natural riverbank and foundations of the main canal from erosion. The water will be released through the spillway and flows back to the river through a lined section of the natural river bank.

Figure 4.4: The sluices and rejection spillway

The main canal is lined with a rectangular shape until 2750 meters from the headworks to avoid severe losses in the conveyance canal. The main canal is crossed by several drainage canals from the upper watershed. There are 6 small drains up to 10 m^3/s and 5 large drainage canals which can damage, erode or flush away the natural riverbank and fundament of the main canal. These drains vary tremendously in discharge as shown before in Table 3.2. The small drains pass over the conveyance canal with *drain* structures. The larger drainage canals are crossing the contour lines, in so called *cross level drain* structures with a concrete lined canal bed, as shown in Figure 4.5. In the design this drainage water can either cross the secondary channel and discharge into the canal, or flow over it and continue in the drainage canal. If there is water in the main channel it can cross the canal and continues it natural drainage flow. The flume in Figure 4.2 allows the Dodota drainage canal only to continue its natural flow since the main canal ends here.

Figure 4.5: Cross level structure at main canal before branch canal 2

Within the scheme there are 7 secondary branch channels, with *diversion* boxes such as depicted in Figure 4.6. The water is proportionally divided up to 1 m^3/s into the secondary channel but can be regulated or closed as well. There are no measurement structures for measuring the water diverted into the secondary channel. The main canal can be closed after the diversion box, in case less water is flowing through the canal and thus to divert more to the specific secondary channel. At the top-end of the diversion box a drop structure is placed.

Figure 4.6: Division box at branch canal 5

The *secondary branch canals* and the largest part of the main canal are earthen canals with a trapezoidal shape, this shape of the canals will inevitably change over time to more rectangular, this is also seen after 5 to 10 years at other schemes. The flow through the canal will be affected since the area is increasing. This is not considered a significant problem because the canal bank and bed will become more compacted and stable and even less erosion sensitive (Designer: H. Aman). To minimise erosion and turbulence in the earthen section of the main canal and the secondary canals, the formula of Manning has been used to calculate the maximum slope in accordance with the canal dimensions. At the start of the project a slope of 5% was assumed acceptable for the secondary canals. If the velocity became greater than 2.5 m/s energy dissipating mechanisms such as drop structures were applied. However after the irrigation trial signs of erosion were already observed. For this reason the other remaining secondary canals have been adapted to a slope of 2%, resulting in higher costs.

The branch canals all have the same *drop structures* such as in Figure 4.7. The presence of drop structures is not uncommon for spate irrigation. The elevation differences within the field are significant and therefore drop structures are essential for maintaining a constant flow. In these drop structures the water level changes with 2m. Along the branch canals every 100-200 meters drop structures are constructed. At the top of the structure, the flow can be interrupted by a metal gate, to raise the head for irrigating the command area. The structure has one or two of-takes at each side. The tertiary outlets can be controlled with the staff gate and are used by the farmers to divert the flood to their fields. Not all drop structures have off-takes, according to the design, an off-take is only allowed with an interval of 300 meters to establish tertiary units of approximately 30ha.

Figure 4.7: Drop structure with 2 off-takes, but without gates installed yet

From Figure 4.6 and Figure 4.7 it can be seen that not all structures are finished yet, but it is clear that all structures which can be open or closed, can be manually operated by metal gates. Here the main question arises how they will be operated and by whom. The next paragraph will go deeper into this.

4.1.3 Operational activities

In compliance with other controlled and large schemes, the Dodota scheme will be jointly managed by the government and the WUA. The organisational structures of management, is further explained in §4.2.1. Briefly, the mixed management of the scheme is based on two levels of management, the operation and maintenance responsibilities will be separated according to the layout of the system. In this way the OWWCE will become responsible for the operation and maintenance of the main and branch canal system. The WUA will be responsible for the operation and maintenance and management of the tertiary irrigation infrastructure and the command area, within the boundaries of the secondary canals. Operational and maintenance activities need to be carried out in accordance to their responsibilities. Included in these responsibilities are the objectives to meet the operational targets indicated in Table 4.1, of which supplemental irrigation for a command area of 5000ha is the final stage.

Table 4.1: Overall operational targets based on served command area

Year	Operational targets
2007	300ha (branch canal five)
2008	800ha (first crop season)
2008	2000ha (second crop season)
2009	5000ha (complete scheme)

The operational target of 2007 was not clear in the beginning, but eventually it covered around 300ha. This year it was planned to irrigate around 800ha for the first crop season and 2000ha for the second crop season. This seems unlikely as much infrastructure still lacks gates and control mechanisms. It needs no clarification that the operation and maintenance was and is also based on these objectives. Nevertheless, the future water allocation and distribution needs to take into account water shortage under way materialise with the aim, to cover a command area of 5000ha.

The Dodota irrigation scheme is a clear example of upstream control with vertical slide gates. As shown, the system can regulate and control the flow in every passage from the sluice gates at the spillway, until it actually reaches field level, at the drop structures. For this reason, the system as it is designed requires a strong organisation, because there are many gates to be operated and adjusted. Not only is it important to assure gates are working properly, but also they need to be operated accordingly to assure an efficient and fair water distribution. The design allows delivery of water to the tertiary units in accordance with the available water supply to the scheme and the actual irrigation need of each unit. By planning the cropping and irrigation demand, sufficient water can be timely allocated. In this way the irrigation water and water demand can be matched. For the operational targets to meet the requirements of the farmers demand in the best way, it is essential to make an irrigation plan. However, especially for spate irrigation it is very difficult to plan the water availability, since the floods can vary tremendously as explained before. Nevertheless by monitoring and evaluation of the control and regulation of flows, the scheme performance can be developed.

Based on the interviews and field observations, it became clear that many of the operational activities discussed so far, are not implemented yet. In 2007, with the ad-hoc irrigation trial to irrigate around 300ha, limited operation activities were carried out as seen in Box 4.1. It turned out, that the regulation of the flows in 2007 was not based on the demands of farmers and that these flows were not measured or monitored either. Only the number of irrigation turns were counted, to see the impact of irrigation on production, which will be clarified in §5.5.

Box 4.1: 2007 Irrigation trial, description of the carried out operation activities

The irrigation season at the end of July until the beginning of September 2007, was arranged in close cooperation and support with the extension services of the ARDO, the CPCB and the DA. Irrigation was managed by the OIDA[20] and coordinated and controlled by four of their irrigation specialists. The OIDA determined that a part of branch canal five would be suitable for an irrigation trial. On this term the DA listed the farmers, who had plots near the branch canal and organised them in groups with the support of the CPCB. Before the irrigation was about to take place, the ARDO coordinated the field preparation with the establishment of bunds to store the flood water. The SNP programme participated to organise the farmers and to make them prepare their fields on behalf of food for work. To make the water distribution possible, a limited amount of water was passing through the rejection spillway and flowing through the main canal and division box 5 into branch canal 5. This was coordinated by OIDA. The farmers were themselves involved in the field application, by using the off-takes of drop-structures. The CPCB had prepared a document with "temporary by-laws" to clarify how the irrigation trial was to take place and on which conditions. Also here the OIDA and the DA supported the farmers with the coordination of the irrigation of their plots.

The operation of the water distribution was more difficult, since the structures that were used for the diversion were also not completely finished. Besides at the headworks and the rejection spillway, metal gates were not yet installed in the diversion boxes or drop structures at the branch canal. In the near future all these gates will be enhanced with a staff gate[21], which makes it possible to estimate flow discharges. This kind of information could contribute to improvements of the regulation and control of the flows and to scheme performances. Another aspect which can make a significant contribution to the water distribution, is the scheduling of irrigation turns, based on crops water demand in the tertiary units, see §5.3.

4.1.4 Maintenance activities

For spate irrigation systems proper maintenance is of major importance to overcome deterioration of the physical condition of the system and to meet operational targets. The design of the scheme is adapted to the environment and constructed to last for a period of at least 20 years. Nevertheless, the system will be highly dependent on proper maintenance. The Dodota Scheme not only has a very long main canal and several long secondary canals. The system is also equipped with several more complicated structures, such as the headworks, drainage structures, division boxes and all the drop-structures. Not to forget the network of tertiary- and field canals and bunds, required for the application to the fields. In this sense the maintenance is a chain of vital links. For the maintenance the organisation of resources and labour are very important. This is one of the main reasons why the Regional government is involved in the management of the main and secondary canals. But despite this, much labour will be required to prepare the fields for irrigation, which will be taken care of by the WUA.

In general three types of maintenance can be distinguished which are; routine, special and deferred maintenance. Routine maintenance is always required and part of the day-to-day management. Special maintenance is required to repair damaged structures and to take care of unforeseen phenomena. If the scheme lacks and needs to be completely adapted and modernised than this is referred to as deferred maintenance. The latter will hopefully not be required on a short notice. But routine and special maintenance will be necessary on a daily or

[20] OIDA was the predecessor of the OWRB.
[21] The staff gate is similar to a large ruler and fixed to the outlets to measure the water-levels H1-H3, which corresponds to a certain flow discharge.

weekly basis. To control and oversee the maintenance several activities such as, planning, scheduling and evaluation are required. The main maintenance activities which can be distinguished are; repair of structures, reshaping of canals (excavating) and bunds, sediment removal from structures and canal bed and weed removal from canal beds and embankments. The importance of maintenance of such a large scheme became clear during the transect walks and field observations. Even if the system was still under construction and only partly used for the irrigation of last year, already deterioration of the system was visible.

Currently the OWWCE is finishing the construction since this date was extended from March with another 3 months. There were many problems with the construction, mainly due to a lack of construction materials. The ongoing construction works and the fact that the scheme management has been not properly implemented yet, as will be explained in §4.2.1 have an impact on the maintenance. For example the sedimentation in front of the headworks, seen in Figure 4.8 was not removed yet, though to prevent it entering the main canal, it should be removed before the irrigation of 2008. Another issue is the flush-gate recently damaged by a flood in April. It is hard to see on the figure, but the flush gate can not be operated anymore since this mechanism has been broken. This is an indication of the major importance of special maintenance since structures can be severely damaged and can become in operational.

Figure 4.8: Sedimentation at the headworks

The division box at branch canal 5 as seen on Figure 4.9 shows the current state. Under the road-bridge and in the division box, a change of bed-level due to severe sedimentation can be observed. Also there are weeds growing on the canal bed, which can slow down the main-canal flow and increase sedimentation rates. If the sediment and weed growth remains, it can block the free passage of water and cause disproportional with drawl by branches, inadequate transport capacities and could cause damage to gates and intakes. Therefore sediment and weed growth should be removed before the irrigation season.

Figure 4.9: Sedimentation at division box

In the branch canals observations of erosion, sedimentation, weed growth on the canal bed and canal embankments were already observed. The trapezoidal shape was deteriorated at some parts by erosion due to heavy rainfall and wind. Also improper stock grazing and passage contributed to this. Rules are required for cattle using the farm bridges instead of crossing the canal. Severe erosion was also observed in branch canal 5, due to the irrigation trial. Watergrass could protect the canal against erosion.

Figure 4.10: Observation of the canals

From these observations and the need to maintain in total 67,3 km of canals, it can be concluded that the maintenance of the system requires a strong and effective organisation. As mentioned before maintenance will be the responsibility of the government for which the OWWCE has been given a mandate. The other maintenance activities which take place in the tertiary unit, will be organised by the WUA. Also here a lot of labour will be required to keep the system in a proper state, to be able to irrigate the fields efficiently. Farmers so far had no knowledge or experience with irrigation, for this reason the farmers are coordinated and guided by local extension services and supported by the SNP program. Box 4.2 shows how field preparation is carried out. What is observed in the field is, that until now, the initiative is not coming directly from the farmers themselves. But when farmers are aware it is for their own benefit, it is likely that they are willing to work and engage in maintenance work on their own land.

Box 4.2: Field preparation by farmers

Last year and this year, farmers with plots in the selected irrigated area have been working to prepare fields as seen in Figure 4.11. This has been established with the support of the SNP. The farmers participating in the program are registered as such and are responsible for preparing a certain part of the field preparation. Here men and woman, whether they are young adults, middle-aged or old people are working together. The works were executed by the use of simple hand-tools, like scoops supplied by the ODPPC. For the preparation of the irrigation for last year some trial bunds has been established. For this year fields have been improved by more bunds and tertiary- and field canals, according to the field layout.

Figure 4.11: Preparing a tertiary canal

The tertiary-, field canals and bunds are constructed according to specific dimensions[22] shown in Figure 4.12, to assure efficient water distribution. The canals are prepared with a slope to ascertain that the flow reaches also the tail end. The canals and bunds are placed according to the field layout to make sure all plots can be reached and can receive irrigation, this is further illustrated in §4.3.1. This year it took around 6 weeks to prepare the fields, farmers were working 2 days a week, on Wednesday and on Friday. Of major importance is to prepare the fields in advance of the irrigation season, to make proper use of the available irrigation water. In the following years these works will be planned, scheduled and executed under the organisation of the WUA.

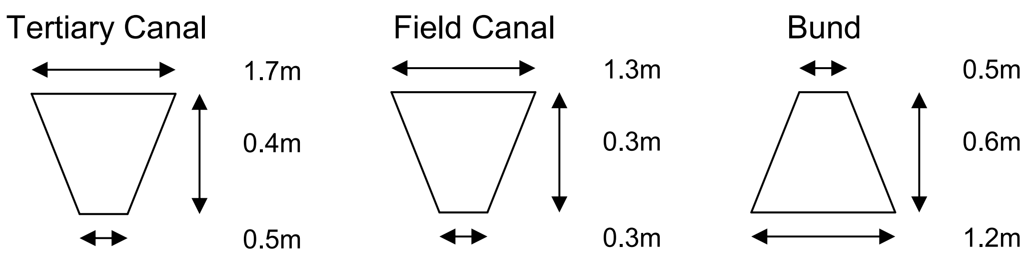


Figure 4.12: Dimension for the field preparation

[22] Calculated by the designer (H. Aman, 2006).

4.2 Organizational activities

4.2.1 Scheme management

For the research it was difficult to get a grip on the scheme management. Not only was the scheme itself completely newly introduced in the project area but also is management. The main issue here was, that even the institution involved in the management, the autonomous OWWCE of the government, was not installed yet. Also the local WUA of the farmers were not implemented yet, but were just about to be established. Another reason which made it difficult was the lack of rain, which made it impossible to observe irrigation during field visits. However even with these setbacks, it was possible to have an impression of the irrigation trial of last year, with the fruitful information and support of the OWRB, irrigation specialists and farmers. Also it was promising to have interviews with government officials to have an idea of how they were intending to manage the scheme. And last but not least, with the final report of the OWWDSE, it was possible to take a close look at how future management will be set-up.

The Dodota irrigation scheme is the first large scale spate irrigation scheme in Ethiopia. For this reason the OWWDSE was consulted[23] to advise the OWRB, on how to manage this scheme in particular. One of the main issues concerning the management was to assure the sustainability of the irrigation scheme. Since the scheme was large, a strong and effective organisation was required. Another point was the capability of the organisation to deal with the maintenance of the headworks and the operation of the network of canals. Based on international and local experience and thus in consideration with the present situations of the farmers and their capacities, it has been concluded to involve the government. In this sense the scheme will be jointly managed by the government and the local farmers. The management of the irrigation scheme is based on the existing regulatory legal frameworks and institutional arrangements[24]. As described in §3.3 many existing institutions were already functioning at *woreda* level. Services such as agricultural extension, input supplies, credit, marketing, capacity building and technical support and trainings for operation and maintenance at tertiary level were already incorporated. However besides these existing institutions, a new autonomous institution will be established for the operation and management activities. This was based on the water resource management strategy, which claimed that for large schemes it is essential to establish self-financing public institutions (Derese, 2008:14). For this reason the regional state mandated the OWWCE, to be responsible for the Dodota spate irrigation scheme and to construct, own, and operate and maintain the scheme. Here for an appropriate cost recovery system, as in line with the objectives of the water policy needs to be developed too. Thus in the future the farmers need to contribute either cash or labour if the economic status of the farmers allows this. Derese, (2008) recommended the government to fund on a reducing scale[25] for the operation and maintenance costs of the main system and secondary canals for a period of at least 5 years.

The OWWCE has expanded the current organisation structure under supervision of the General Manager with the Scheme Administration Division, which will be responsible for the medium and large-scale irrigation and water supply schemes of the region. To make this possible autonomous units are needed to coordinate the direct management, operation and maintenance activities of larger projects like the Dodota Irrigation scheme. For this project the so called Boru-Dodota Spate Irrigation Scheme O&M Unit will be coordinated and directed

[23] The term of reference was to put in place efficient institutional setups that ensure the sustainability of the Dodota scheme. This study was conducted in the same period as my field study (final report in June).
[24] The federal water resource management policy, Ethiopian water sector strategy, Ethiopian water resource management proclamation and regulation and the cooperative societies proclamation.
[25] The government will determine the possible contribution of the farmers and cover the remaining costs.

by the Irrigation Schemes Operation Coordination Service Division and the local District board of management. This local unit will be responsible for the system infrastructure of the main canal and the secondary canals. To carry out the operation and maintenance activities the unit will be capacitated with several staff members. Chief responsible is the unit coordinator, who will report to the ISOCSD and the district board and supervise the day to day management. For the day to day management and the implementation and execution of the actual operation and maintenance an engineer will be responsible. The engineer will control the water distribution and assesses information on water supply and performance in order to enhance the planning and improve the management. To make this possible several supportive employees are hired as permanent staff, or either as temporarily workers. An overview of the organisation structure as proposed in the operation and maintenance manual by Derese (2008) is given in Figure 4.13

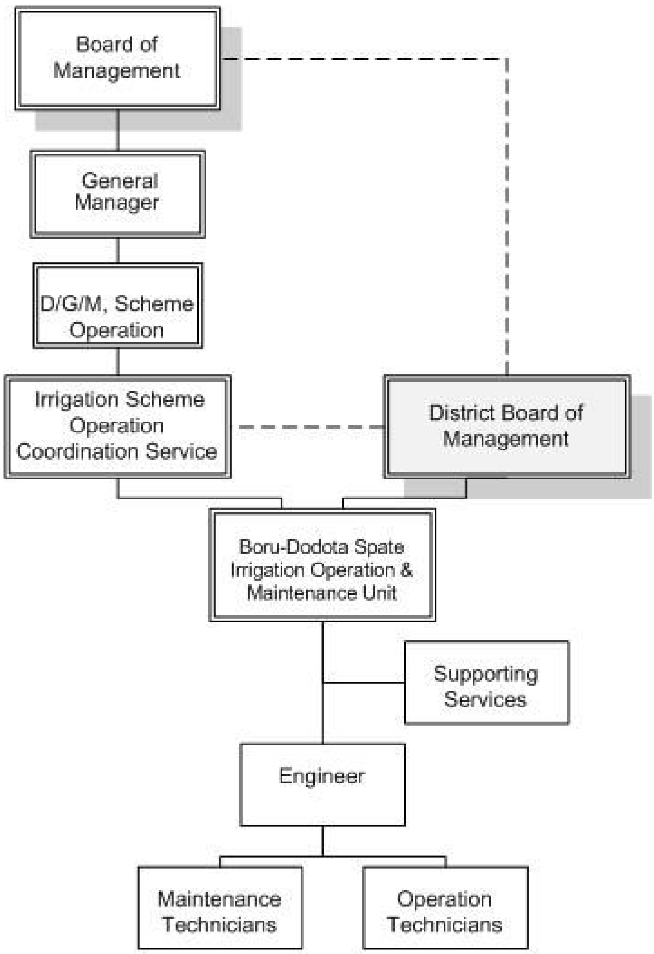


Figure 4.13: Proposed structure for the operation and maintenance

Operation technicians will be hired for the operation of the main canals and branch canals, these so called gate keepers will be responsible for the distribution and division of flood water, to meet the demands of the farmers. In this sense they distribute and control the flows that each division box or intake must deliver, by opening or closing gates or valves. In their job description (Derese, 2008:p24) is mentioned “the collection of the water requests”, “the preparation of the daily forms of the water delivery” and “the measuring of released quantities to farmers, if possible”. It is not clearly mentioned how this will be achieved and this will be further discussed in §4.3.1. The gate-keepers will also control the operation of the headworks and the spillway on request of the engineer. Besides these operation duties they will keep an eye on unauthorized use of water and support acquiring information about silt accumulation in the canals to assure proper operation and maintenance. The maintenance technicians are executing maintenance activities on the infrastructure of the system and make sure the main canal and secondary canals are in proper state. They have the capacity to repair the canal embankments and remove blockages or obstacles in the irrigation canals and the drainage canals. Also the removal of accumulated silt and vegetative growth changing the original shape of the canals is part of their job description. Next to the irrigation infrastructure, the regularly roads along the main canal and bridges will be inspected and properly maintained to assure passage and safety.

As mentioned before the tertiary infrastructure and the command area will be managed by the farmers themselves. Also this requires a strong organisation to assure as what is called in §2.5 the "critical mass", required for operation and maintenance works. To address this institutional need, so called Water User Associations (WUAs) will be established based on the present Peasant Associations. Previously farmers were not involved in operation and maintaining irrigation infrastructure since only rainfed agriculture was practised. However farmers need to become part of the system and participate in decision making and the management. The WUA will be established according to the separated secondary canals and their command area, within the hydraulic boundaries of the branch canals. In this way 7 different WUA can be distinguished. The WUAs will become responsible for the management, operation and maintenance of the tertiary units beginning from the tertiary head regulator. Based on tertiary blocks, farmers will be organised in groups according to their farm plots. Here group leaders or Water User Group Leaders (WUGL) will be selected. In this way operation and maintenance activities can be more efficiently organised. These group leaders are given an important role by (Derese, 2008), namely to coordinate maintenance works and distribute the water to the different water users, in accordance with the agreed rate of supply and delivery periods, see also §4.3.1. Another important task of the WUGL is, to report water users who are violating rules or bylaws which will be further discussed in §4.2.4. A future role for the WUGL is also to collect water charges if these are agreed upon. The WUAs will be established, according to the organisation structure shown in Figure 4.14

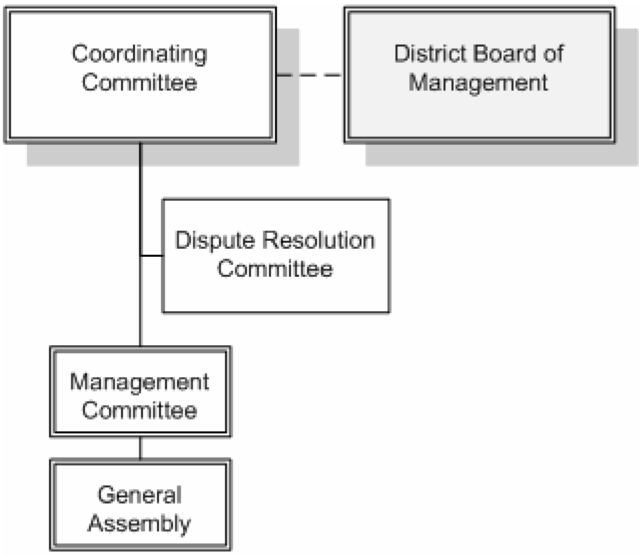


Figure 4.14: Organisation structure of the Water User Associations (WUAs)

All members of the same water user association within the command area of a particular branch will be gathered in the General Assembly[26]. Based on elections, this group will decide which members take a place in the WUA Management Committee, which is the supervisory organ for the General Assembly. The Management Committee is involved in the supervision and coordination of efficient water distribution and maintenance in the command areas, with a

[26] The number of farmers in the General Assembly is dependent on the command area of the specific branch and varies in the range of several hundred farmers to thousand farmers.

focus on the tertiary units concerning the tertiary canals and quaternary canals. Another task for the Committee will be the coordination of water fee payments in the future. To be able to coordinate al these activities, the committee will formulate, set up and implement the bylaws, which will be used upon by its members. If members or groups are violating these agreements, corrective measures will be assigned in accordance with the by law. Besides the management committee a Dispute Resolution committee is formed, to deal with disputes and disagreements in the WUA concerned. If they fail to settle the dispute the higher Coordination committee can be involved. To manage the scheme completely the WUA Coordinating Committee will be formed. Here the representatives of all WUAs Management Committees, thus 7 in total will be accountable and responsible for the supervision and coordination of the WUAs concerning the operation and day-to-day management. Important issues to all WUA, such as water allocation and distribution amongst the WUA, and cross cutting issues between their boundaries, which can not be solved by the WUA Management Committee, need to be addressed here. The chairman of the WUA Coordinating committee will take a place in the District board of management, mentioned earlier to represent al the WUAs. This Board will supervise the coordination unit with the SIOCD. In consideration to the proposed jointly or mixed management, it is remarkable to find actually only the chairman of the WUA coordination committee taking place in the District Management Board. Other members in this board are from the District Administration office, BARD office, CPC office, BWRD office, the BDS O&M Unit and the WUA Coordinating Committee. In relation to the responsibilities and direct relation of the WUA with the Boru-Dodota Spate Irrigation Scheme O&M Unit, it is more likely to have a direct link of the day-to-day management and link common activities, since they are similar.

4.2.2 Land rights and tenure

The land in the project area is managed by the Peasant Association and the *woreda* Administration office. The latter is responsible for the collection of the tax (which is paid only according to the plot size) and is involved as mediator in land disputes. Moreover the PA chairman will be involved, since land exchange or transfer can only be arranged in consultation with the PA's chairman and is completely based on the government policies. At local level, land management is entirely based on government policy and older customary rights have been abolished as illustrated in Box 4.3.

Box 4.3: Brief illustration of the history of the land system in Ethiopia (Rahmato, 2004)

For Ethiopia the three decades since the mid-1970s have been times of profound and rapid change accompanied by a high degree of institutional instability, particular in the rural areas. The country witnessed three political regimes with significant economic and social reforms impacting on ownership, state structures and resource management. Reform defined the parameters of the property system in force today including rights of access to land and to environmental resources. The land reform of the Derg regime is still the basis of the present land system and brought an end to the archaic land system of the imperial regime and the exploitation of the peasant population. However in its turn it was also a cause for rural insecurity and growing poverty (Dessalegn in Rahmato, 2004). The reform abolished all customary rights to land and vested in the state the power to redefine right of property and access to land. The landed class was dispossessed and their land was distributed to the peasants who were organized in PAs and entitled to land as residents of their kebeles. After this land could only be redistributed through periodic re-distributions[27].

In Ethiopia the land rights are based on the constitution and federal policy but can differ in some aspects from one region to another. The Oromia legislation is legitimate for the case

[27] Land is newly divided and fragmented by the government, in order to give access to land for young people.

study area and is in comparison to other regions in many respects much better. Some important aspects are for instance that Oromia has implemented the user right document recently, gives land holding rights to the family and has established adjudication of land disputes through the court. In Oromia, men and woman have equal rights to land, since the family holding will be registered and certificates are given in both the name of the husband and wife. The land policy goes even further and article 6 and 15.2 make clear that in case of divorce the family plot will be divided equally between them.

As in the whole country, land cannot be sold or exchanged in any way as stated in the Oromia legislation in article 4.1. But there are many constraints for this land policy, especially in combination with article 5.1, which states that any resident in the region of 18 years or older, who wishes to live by farming has the right to access land free of charge. Unfortunately there is a severe shortage of farmland in all parts of the country which results in growing landlessness on the one hand and the progressively decreasing of farm plots on the other (Rahmato, 2004). The current land policy makes it almost impossible for farmers to find other sources of income elsewhere, since the landholding right in most other regions is linked to residence in the *kebelle*. However in Oromia, article 15 states that the rights to land will not be terminated, if the holder leaves his /her *kebelle* and resides elsewhere. This gives land holders the possibility to look for alternatives and at the same time to keep their land rights. Land can be sub rented which gives also access to land for others. In interviews some farmers explained that they were actually landless but had access to farm land with the introduction of the document. In case land holding is linked to actual residence, land access is more limited and depended on actual land redistribution.

Oromia prohibits further redistribution of land, except in cases involving land in irrigation schemes in article 14.1. Yet this only applies to perennial irrigation schemes, which implies that in case of the Dodota irrigation scheme no redistribution will take place. In a certain way this could lead to income disparity, but with the introduction of the user right document in 2004/2005 this argument is redrawn and it actually improves the dynamic land market. However, land is not recognised for collateral by banks, since it is still owned by the state. The main reasons to implement the user right document by the state was; "that right holders will be issued documentation as an assurance to their rights as a means to promote tenure security" (Rahmato, 2004:18). According to the government, farmers develop a sense of ownership that they will not lose their plots in the future and they would invest in their lands. In practice it implies that the land is registered by the PA and the plot is measured by the farmer and demarcated with strict boundaries. This was also seen in the study area where footpaths and bushes were used as boundaries and most fields had a rectangular shape. From the interviews it became clear that farmers were not afraid to lose their lands, but were not motivated to invest in their lands, because the lack of rain effected their production, this will be further illustrated in §5.1.

Rights to holders are described in article 6, which affirms that the holder rights are for life and these rights can not be deprived under any circumstances, unless the land in question is needed for investment by the state for the public good, in this case the person will be compensated for all the investment on the land. This accounts also for the Dodota irrigation scheme since part of the farmland had to make place for canals and structures. Nevertheless farmers are more than compensated since their plots will receive irrigation water, which will increase agricultural production and the value of the land and thus will give much better rents. The possibilities to sub rent land have an implication for the organisation of the WUA, since they are not the legitimate land holders, this will be further explained in §4.3.1.

As a right holder you are entitled to lease part of your land to others (up to half of their plot). For farmers there are several means to obtain and share land for cultivation. The different transfers can be favoured in consideration to the situation of the households and land holders, in this sense land transfers can help landholders to cope with difficult situations. Besides the landholders there are the landless in need of farmland and enterprising peasants, who trying to escape poverty or do want to improve their income (Rahmato, 2004). According to Rahmato (2004) the most common forms of short-term land transfer in Ethiopia are; share-cropping, rentals, land loans and limited “leases”. Overall share cropping and rentals are the most common forms of land transactions. In case of share cropping, the land is supplied by one farmer and the other contracting farmer takes care of all other inputs. At the end, the production can be shared according to the agreements, based on a certain percentage of the harvest or a fixed share of the harvest. For this tenure system, crop management is very important because it has a significant impact on the yields. Rentals are favoured in more poor communities to acquire money to gain access to certain required assets, such as labour or oxen to enable farming on their remaining lands (Rahmato, 2004). Farmers sub renting their land can determine rents and tenure arrangement for their land according to some specific variables. There is also legislation concerning the lease period. If the lessee employs “traditional technology” he can rent the land for a maximum period of three years. If he/she employs “modern technology”, this period can be up to 15 years. The legislation defines modern technology as mechanisation and or the use of agrochemical and improved seeds. From interviews it became clear there can be a huge difference of sometimes more than 15 times between rainfed or irrigated land[28]. Besides this there is a price difference according to the crop, because this can influence the future quality of the land. Also the use of fertiliser will influence the price of renting. If these are used the price will be higher because the land is adapted to it. Finally the location (next to the road, easy for transport) will have an impact on the final renting price. Farmers who are renting land most commonly receive an annual contract. The sub renter can decide to change the price, or find another renter who is taking better care of their lands. In the project area many farmers were renting land, but mostly for short periods to make sure their land was properly taken care of. If holders are unable to personally cultivate their land, they are allowed to have it farmed by hired labour. In this case land loans are considered, this can be favoured by woman headed households with rights to land, elderly households, or households who are incapable of taking care of the land in relation to ill-health (Rahmato, 2004). Next to the short-term land transfers there are also long-term transfers, if these are considered, the inheritance and endowment are most commonly practised, (Rahmato, 2004). In these cases the lands are given or borrowed to wives, family or children and are free of charge.

Besides these rights given to land holders there are a number of conditional ties that the right holder is obligated to comply with. According to Rahmato (2004) these include good management of the land, soil and water conservation, refrain planting “harmful” vegetation, including eucalyptus and cactus and leave so called “mother trees”[29] standing on farm plots. For disagreements about land disputes which can not be solved by the PA leader and the *woreda* Administration office, article 25 makes clear that the Oromia legislation relies on the rule of law, to resolve land conflicts and to decide upon the penalties. Right holders which violate the provisions stipulated in the legislation are sued in accordance with existing civil or criminal law. In this way land disputes are judged in the first instance by the *kebele* social court. If the conflict here is not resolved to satisfaction of all the disputants concerned, they may be taken to the *woreda* court.

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[28] Here is referred to perennial irrigation and commercial crop production.

[29] These are referred to as local tree species which should be conserved and sustained in the area.

4.2.3 Water rights and rules

Unlike with the regional land rights, the Ethiopian government has a National Water Resource Management Policy. This policy is issued by the federal government in 1999.

"The Ethiopian Water Resource Management Policy has a primary goal to promote efforts towards efficient, effective, equitable and optimum utilization of the available water resources. The overall objective of the policy is to enhance the well-being and productivity of the people through sustainable development of water resources for equitable social and economical benefits" (MOWR, 2004:56).

To make this possible, the policy has been developed with the concept of Integrated Water Resource Management (IWRM), into an integrated approach with fundamental principles that guide the development and management of water resources, these are given in Box 4.4.

Box 4.4: Fundamentals of the National Water Resource Management Policy of Ethiopia

- *Water is a naturally endowed commonly owned property of the people and the state.*
- *As conditions permit, citizens shall have access to safe water for basic human needs.*
- *Water is recognized as a social and economic good in order to contribute significantly to sustainable social and economic development.*
- *Water Resources Management shall ensure social equity and economic efficiency, system reliability and sustainability.*
- *Water Resources Management is decentralized and as well is rural centred and participatory.*
- *Promotion of participation of all relevant stakeholders, particularly women's participation in all endeavours of water resources development and management*

The management of water resources of Ethiopia is in accordance with article 6:4 about a permit system. Not all uses require permits, like water use from hand-dug wells and use of water for traditional irrigation, artisanal mining, for traditional animal rearing as well as water mills. The legal provision in the proclamation with regard to ownership, allocation and apportionment makes clear that the development, management, utilization and protection of all water resources in the country is in hands of the federal government. There is no other law or water legislation used and issued at regional and or local level. It is stated in article 8:1 that the Ministry of Water Resources shall be responsible for the planning, management, utilization and protection of water resources and in article 8:1:c that it shall determine the allocation and manner of use of water resources among various uses and users. Thus regional states and local administrative bodies are obliged by law, to implement the water policy in accordance with the directives and guidelines provided by the Federal Ministry of Water Resources. This is also seen in the project area where the management of water resource management are rurally centred and participatory as stated in article 27 "the supervising body may, in consultation with the appropriate public bodies, encourage the establishment of water users' associations, as it deems necessary to utilize water for beneficial use". For the Dodota irrigation scheme a WUA will be established which are in line with the policy. Beside the management of water resources, the water policy also directs the water allocation and apportionment, see §4.3.2.

The national water policy is made for three sectors, water supply and sanitation, irrigation and hydropower. According to Teshome (2003:43) the policy objective of the irrigation sector include the following, illustrated in Box 4.5.

Box 4.5: Policy objective of the irrigation sector

- *To achieve food production at household level by developing and promoting small-scale irrigated agriculture operated at farmer level.*
- *Promotion of small, medium and large scale irrigated agriculture to supply raw materials for industry; and at national level, to achieve food security and earn foreign currency.*
- *To promote manageable, sustainable, equitable, reliable as well as environment-friendly irrigation system.;*
- *To develop techniques of water use efficiency, waste water control, maintenance of irrigation infrastructure and drainage (MoWR, 1999 (1991 E.C):21).*

Another more recent objective of the Federal government for the irrigation sector is; "The development of appropriate cost recovery systems and mechanisms for all irrigation systems" (Derese, 2008). Based on this objective the OWRB has given the mandate to the OWWCE as a self financing autonomous institution. Also deriving from this objective is the implementation from Water User Cooperatives instead of Water User Associations. According to Derese (2008) WUA are not considered as a legal entity, and therefore not given any financial support. This makes it more difficult for these associations to be able to take care for the management operation and maintenance of the system. Therefore the cooperatives will be established according to the guiding principle of the cooperative societies proclamation no. 147/1998. From interviews with officials of the CPCB office involved in the establishment of Water User Cooperative, there are several advantages for the farmers to join cooperatives, this is summarised in Table 4.2.

Table 4.2: Comparison between WUC and WUA

Description	Water User Cooperative	Water User Association
Entity	Legal entity (CPCB)	Association certified by Ministry of Justice
Rights and rules	Cooperative law, (internal) bylaws	International rules, (internal) bylaws.
Purposes	Multi purpose	Proper water distribution
Organisational structure	Board members, committees administration, assemblies	Chosen leaders, committees, assemblies
Financial support	Subsidies, credit and financial support	Not supported
Risks (involvements)	Responsibility own share	None (can collect fee)
Profit	Dividend	Not based on profit
Structure	Civil and economic	Civil

In the project area, the WUA will be first established to assure fair utilization of water for beneficial uses and later these associations will become cooperatives. As seen in Table 4.2 both organisations use by-laws, but this is a complete new feature in the area. Until last year farmers have not been confronted with so called water rights, as farming was completely dependent on rainfall. However with the new irrigation system, the floods will be shared based on water rights and distribution rules, in this way the water will be distributed, allocated and applied to the fields.

Last year in July 2007, farmers have experienced irrigation for the first time. In the study area preliminary water rights have been used to regulate this distribution. This year unfortunately no irrigation was observed during the study period but information was obtained from field visits, interviews and secondary data.

The irrigation last year can be considered more like an irrigation trial or experiment. The preparation to actually make this irrigation possible was "ad-hoc" and the water was distributed more or less randomly. This becomes obvious from how this irrigation term has been established. This is clearly illustrated by an interview with an engineer from the base camp in Box 4.6.

Box 4.6: Interview about the ad-hoc irrigation of 2007

"Higher officials, visiting the site, observed water stress and came up with the idea to apply these fields with water. At this time the construction works were all but finished, nevertheless with some bypasses it was possible to divert water from the headworks up to several drop structures in branch canal 5. Before actual irrigation some things needed to be arranged first, like the farmers needed to be organised and they needed some rules to share the water. So irrigation took place"…

Irrigation took place on branch canal 5 near the small village Amigna Debasso for an area of around 300ha. The development agents made groups of farmers. Farmers with plots receiving irrigation from the same off-take were in the same group. None of these farmers had any experience with irrigation. There were many problems and fields were not prepared properly for irrigation, as farmer Bestiga Dugo explains in Box 4.7.

Box 4.7: Interview with farmer Bestiga Dugo from Amigna Debaso

Bestiga Dugo wasn't expecting any irrigation water, but diverted it when it was flowing near his farm, he said "we saw water and took it". But the water came too late, the wheat was already wilting. He explains; "it is better to apply water when the crop is still growing". Many plants died and the difference between possible yields of 6t/ha and only 1t/ha (0.2 t per 0.25Ha) is significant. About the irrigation term he replied "Last irrigation term everybody had conflicts over the share of water and nobody knew how to exactly use it". He didn't know how long it took to get the water at the end of the field. It was also difficult to get the water everywhere and some parts didn't get water. The shallow water sheet was not sufficient and there was not enough depth. Besides this the field wasn't prepared well, the ploughing wasn't in the direction of the contour lines, which made the irrigation difficult. He stopped the irrigation when the field was saturated.

The water distribution would not have been possible without taking into account some basic rules as discussed earlier in §2.4. Before the irrigation term actually took place the CPCB office, the DA and the PA leader organised farmers and established temporary by-laws. The farmers were informed and given a document written in Amharic[30] with the by-laws and an indication of the punitive measures[31]. These by-laws were similar to the common rules and will be discussed one by one according to the order given in Table 4.3.

Table 4.3: Identification of water rights and rules in the study area.

Water rights and rules (Steenbergen, 2005)	used last year
A Demarcation of land entitled to irrigation	√
B Rules on breaking diversion bunds	√
C Proportion of the flow going to different flood channels and fields	√
D Sequence in which the different fields along a flood channel are watered	Partial
E The depth of irrigation that each field is to receive	-
F Practices regarding second and third water turns	-
G Rules on small and big floods.	-

[30] National language of Ethiopia.
[31] Fines, given in the Ethiopian currency (Birr).

A - For the Dodota Irrigation scheme the demarcation of land entitled to irrigation is encapsulated within the physical construction. The system will not be confronted with changes of river courses and flood breaches, since the diversion of the Boru stream is established with a permanent head work and assured to solely divert the Boru stream. Within the system the water is allocated to different branch canals serving their command area. The system is designed for the command area and will also not be confronted with increased or more upstream land development. In this sense the irrigation scheme has already set the boundaries or demarcation of irrigated land. The design of the irrigation system has made tertiary units, which gives a clear instruction to farmers to prepare their fields if they intend to receive irrigation water. Last year only a specific part of branch canal five was irrigated which was determined by OIDA. Farmers with plots in the irrigated area were informed and their lands were prepared with the support of the SNP. The demarcation of irrigated land was simply recognized by the bunds. The bunds were created by rasping the top soil together. For this year and coming years the demarcated land will be prepared accordingly to the operational targets in Table 4.1 and directed by the WUA. With the development and increasing command area there will be a competing claim for irrigation water. Even with the demarcation of irrigated area within the design, it is questionable whether there will be sufficient water available for 5000ha.

B - For the water distribution field bunds and field canals are used as will be shown in §4.3.1. From interviews with the farmers it became apparent that the bunds or canals at the fields are not necessarily situated at the boundaries of different land users. Some farmers have their own plots crossed by field canals or bunds. This makes it very hard to make a distinction between the lands used by different farmers. The normal rule which is practised by farmers is to not plough at the boundary, in this case there is a strip of unploughed land between the different owners. For rainfed agriculture this is suitable, but in case with irrigation it can become an invisible boundary leading to conflicts. Another issue in the study area was the breaching of bunds. In general a bund is breached to divert the water to the next field in so called "field to field" irrigation. However, plots were irrigated from a field canal instead: farmers were only allowed to take water from the field canals and not allowed to break any bund. In practice it appeared that the field canals were not prepared and breaching was required. The question here was, by whom and when was it allowed to breach? In general the moment of breaching can be dependent on the depth or based on a certain time limit. But because of a lack of clear guidelines on these methods, farmers were just irrigating until the fields were saturated, according to their opinion and then they broke the bund. Given the bad preparation of the fields and the fact that the farmers were so inexperienced and unaware of the application of irrigation water, it was decided to not fine the farmers for disobeying the rules. For 2008, it will be different since the fields will be prepared according to the design layout. Breaching a bund is a violation which will be punished with a fine ranging from 50 to 100 Birr (about US$ 4.2 to 8.4), depending on the agreements within the by-laws of the WUA concerned.

C - Within the design of the Dodota irrigation scheme the water is proportionally distributed along the main canal. Within the secondary canals water can be rotationally distributed. But as explained before with the installation of vertical sluice gates, the system also has upstream control. This makes the distribution very flexible but hard to control and manage. With the irrigation of last year only one branch canal (5) was used and supplied with 1 m^3/s. In the future the overall scheme management needs to make a distribution plan and set priorities, this will be further discussed in §4.3.2. In general it is clear that the control of water flow is in the hands of the OWWCE and farmers are only allowed to take water from the tertiary unit in accordance with permission given to the WUA. The farmers can take water from the off-takes and distribute and apply it to their fields, by blocking the field canals or if necessary by breaching bunds.

D - This rule has the same implications as the previous one. With the upstream control it is possible to regulate and control the flows entering each of the branch canals and also the order. However one should not forget that the command areas are not similar, this implies that possible rotational water distribution for the main canal needs also to be considered. Another alternative for allocation could be interesting if there is only very little rainfall in the catchment area, it this case it could be decided to only irrigate the upstream users to avoid further losses by distribution to downstream users. For the irrigation of last year the sequence was not an issue, since only one branch canal was being used and so far the rule or the setup of this rule has not been formulated yet. However it is clear that in the future al the branch canals will be managed by different WUAs together with the OWCCE and both have to decide upon the allocation in the District Board of Management. A suggestion for this allocation is further discussed in §4.3.2.

E - This rule is of major importance for the coordination and control when irrigation is applied at field level. Not only can it improve the efficiency, it also assures that water is distributed more fairly. In this way losses of over irrigation can be avoided and available water can be shared amongst more water users. Already from Box 4.7 it was clear that the implementation and guidelines for irrigation were missing. Farmers determined when fields were saturated based on their opinion, instead of using a certain irrigation depth or an application time for irrigation. To overcome this, new guidelines are required. Unfortunately the setup of these guidelines is not easily established and depends on many aspects further discussed in§5.3.

F - Another critical rule for the application at field level is, the practice regarding amount of water turns. For spate irrigation in general it is very hard to determine irrigation intervals related to soil types and different crops, since the water source is unreliable. The soil moisture is of great importance here, it is not only about the amount of turns but whether these turns were efficient in relation to the actual irrigation depth reached. The Dodota irrigation scheme is dependent on the semi-perennial river but has also a very large command area, therefore it is doubtful whether it is possible to receive irrigation on a regular base. Last year, as illustrated in Box 4.7, farmers were able to take many turns. According to the farmers, fields can be irrigated more than once, as long as there is sufficient water available, but this can lead to severe conflicts. Also seen last year from secondary data is that upstream farmers were able to irrigate up to ten times, leaving less water for the downstream users. To overcome these issues, farmers should only be allowed to irrigate again, if permission is granted by the WUA. If farmers neglect this rule, they should be given a fine or forced to skip the next irrigation turn.

G - This last rule is related to the allocation based on the size of floods. The design of the Dodota irrigation scheme and the semi-perennial source limited the impact of different flood sizes. Therefore an additional rule is not required to deal with different floods and allocation at scheme level can be arranged based on rules C and D.

From the discussion of the rules above it is clear that the irrigation term of last year was in a preliminary stage. The practices of the farmers need to be coordinated and controlled by the WUA. In general, by-laws for WUAs are for the management of a complete system, thus scheme as well as at field level. For the Dodota system the management at field level is completely up to the WUA. By-laws interesting for the WUA and thus farmers are therefore mostly concerned with the application of irrigation at field level. At scheme level the rules related to the allocation like C and D need to be coordinated and controlled by the OWWCE in agreement with the WUAs. Since the scheme will be jointly managed, the setup of the by-laws needs to be adapted too. A proposition about the setup of the bylaws forthcoming from this discussion is presented in Box 4.8.

Box 4.8: Possible setup of the bylaws based on the discussion of water rights

A Only farmland can be irrigated within the boundaries of the tertiary unit.

B It is not allowed to breach any bund and water can only be taken from field canals.
- If field canals are not in place or working properly, bunds can only be breached by the actual presence of the farmers which plots are being irrigated and the actual presence of the farmers to whom fields it will be diverted
- If bunds are breached a fine of …. should be paid to the WUA.

C Water is allocated in accordance to the Allocation plan decided upon by the District Board of Management.

It is only allowed to take water from the off-take if permission is granted to the WUA.

- If water is taken without permission of the WUA a fine of …. should be paid to the WUA and the farmer is not allowed to take water the first next coming turn.
- If water is taken from the main canal or secondary canals a fine of …. should be paid to the WUA.

D Water is allocated in accordance to the Allocation plan decided upon by the District Board of Management.

E Irrigation water is applied in accordance with the guidelines based on crops and plot size.

- If more water is used for irrigation a fine of …. should be paid to the WUA.

F To take irrigation water for a second turn or more is only allowed if permission is granted by the WUA

- If water is taken without permission of the WUA a fine of …. should be paid to the WUA and the farmer is not allowed to take water the first next coming turn.

4.2.4 Conflict management

The Oromia government has invested to construct and establish the Dodota irrigation scheme. Not only the construction but also the follow up will be with supervision of the government, but not without the participation of the farmers. In the project area the national rules regarding the land rights are already implemented, but the water rights are in a preliminary stage as seen before. For this year and coming years the water rights and rules should be improved, with additional rules and adjusted to deal with the issues discussed in the previous paragraphs. If these rules are not practised, problems such as up-downstream conflicts regarding water turns can arise. To overcome such issues in the first place, all members from the WUAs need to be aware of the rules and the punitive measures. Rules can be enforced based on codification together with the establishment of the WUA, in this way the operation and maintenance at field level is initially safeguarded. However there are several other threats to be considered and taken care of, before fair and efficient water distribution can be established in the Dodota irrigation scheme. One of the major issues coming forward from §4.2.1 is the responsibilities delegated by the WUA to the so called WUL[32]. This person is the main coordinator and controller of irrigation activities and supervises maintenance works at tertiary level under a WUA. This important role is apparently to be given to a farmer without any experience or

[32] Water User Association Leader (chosen by farmers in the same tertiary unit).

training. Kebebew and Bose (2007:8) their observation and report underlines there have been many conflicts and concluded that; "Lack of field canal net work in the command area, coupled with less co-ordination among users and lack of water distribution rules, was also contributing to the difficulties". Besides the role for coordination and control, this person is also the safe keeper and has to undertake action in case farmers are violating the rules. It is important to establish sufficient enforcement to encounter farmers from disobeying rules. Conversely the system is designed to distribute water until the tertiary units which enables farmers to easily take water, even if they are not allowed. Therefore it should be considered to involve the operation technicians from the OWWCE as additional controllers for the irrigation activities at the tertiary units, during operation. Violations of rules are not uncommon and in many irrigation systems farmers are making illegal settlements (with presents or bribes) to receive more irrigation water. In this sense giving much control to unqualified persons can cause corruption, which could hurt the system on the long term, as water is distributed unfairly and farmers could loose trust. It would be disastrous for the system if the farmers are not willing to contribute to the maintenance works as discussed in §2.5. The farmers are given rights, but they also have obligations and they should act in accordance with this. The government supports the establishment of community participation; since farmers can be more convinced they can receive irrigation with proper operation and maintenance. Teshome (2003) showed how in a WUA farmers were not willing to participate, if they would not receive irrigation in any case. Besides this important reason for willingness to contribute there are reasons which can make farmers neglect to contribute. Teshome (2003) illustrates a case where farmers prefer to pay for the fines, which were given by the WUAs for not participating, instead of contributing. Another case is about sharecroppers, who are not taking management responsibilities, due to an inappropriate incentive structure for cultivation on a temporary base. The latter directly indicates that newcomers will have to take over the rights and obligations in case of renting land. Appropriate incentives structures, fines and enforcements of rules are thus of great importance. Whether farmers will comply with the obligations can be considered as a threat and in the future farmers will have another obligation, namely to contribute to the maintenance cost based on cost recovery. Farmers are maybe not able or willing to contribute to the maintenance costs. In any way, same here, this should be avoided and proper maintenance and operation is thus required and essential. To achieve best performance it will be of major importance to maintain interaction between the WUA and the OWWCE, since they are both responsible for the management of the scheme. Therefore the WUA should not be overseen to participate in the decision-making at scheme level within the District Management Board, since they are essential to establish community participation.

4.3 Water use activities

4.3.1 Water distribution

The water distribution at field level requires the participation of farmers to take part in the coordination and control of the application of irrigation water. Especially for the farmers in the Dodota irrigation scheme this is very challenging, since farmers do not have any experience with irrigation. One of the difficulties being faced was the preparation of the fields for flood irrigation, eventually there were tertiary canals and bunds, but there were no field canals prepared. This made it more difficult to irrigate because field-to-field irrigation was not embedded in the temporary rules. Another issue was the lack of guideline for the irrigation time or depth as explained before. The lack of experience, preparation and rules made the irrigation term of last year rather chaotic and hard to coordinate and control. To support the farmers OIDA send four irrigation specialists in advance. Kebebew and Bose (2007) were two of those specialists and executed an on-farm assessment of the Boru spate irrigation system during the irrigation and made some observations from the water distribution at field level. Many difficulties have been observed, illustrated in Box 4.9.

Box 4.9: Field observation from Kebebew and Bose (2007)

> "Farmers do not have experience of using earthen bunds to manage spate flows. And they insist to distribute available flows to large fields as much as possible, rather than keeping a layer of water on single plot which (they consider) might create water logging problem. In some plots, the elevation of bunds is too high above the ground, and also has narrow spacing that 'interrupt' irrigation and farming operation. On the other hand, since the inflow water to the fields was not so large, in bund-less fields, farmers could easily manage the water (easily distributes and irrigate faster)".

Not only the field layout caused problems: another constraint was the idea of farmers about how to irrigate their fields. Their observation showed that farmers have a lack of experience and also a lack of knowledge. This is one of the main reasons why training and education for farmers is so important; it can contribute to improve the field application and improve the efficiency, this will be further discussed in §5.6 .At the other side the observation showed that farmers succeeded to guide the water to the plots and managed to control the flow. The actual discharge coming through the off-takes was hard to define but according to an interview with farmer Girma Mamo, "it was sufficient and many off-takes could be used at the same time". Moreover in the future it will be possible to determine the discharge with the staff gauge. Estimates about the discharge from the designer and specialists vary between 30 to 50 litres per second, which indicates that around 20[33] off-takes could be used at the same time. This requires a strong organisation and efficient water distribution at field level. For this year the lateral is improved and based on a field design with tertiary and field canals and bunds as shown in Figure 4.15. The design has long tertiary canals in the downstream direction along the secondary canal and also in the transverse direction to assure irrigation to remote plots. The tertiary canals are long since the distance between off-takes is around 300 meters to establish tertiary units of around 30ha. The water is distributed through the tertiary and or field canal until the plots, by blocking the field canal the water is flowing on their fields. The water distribution will be coordinated and controlled by the WUA. At field level the tertiary units are managed by the WUL. This leader will be responsible to coordinate and control the rate of supply and delivery periods. With the by-laws discussed before, the farmers need to cooperate to irrigate their fields.

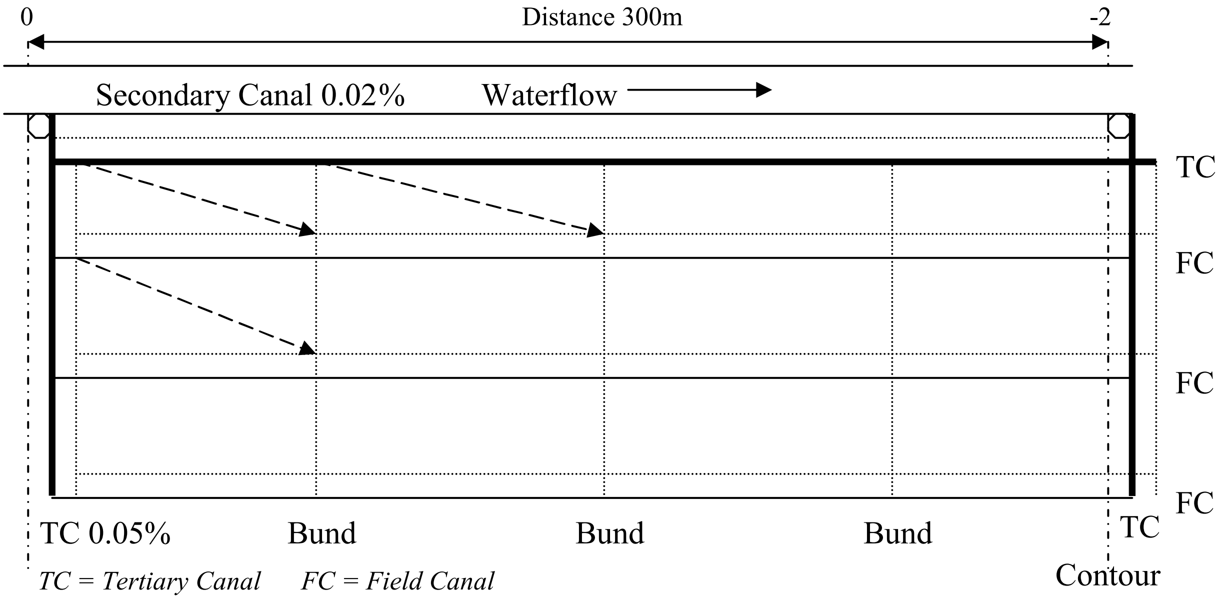


Figure 4.15: Water distribution at field level

[33] 20 Off-takes, with a maximum flow in the branch canal of $1 m^3/s$ and without distribution losses. The infrastructure makes it possible to block the flow passing through the drop-structure to gain extra head, but this will not be allowed for farmers in the future, because this would cut-off downstream users.

4.3.2 Water allocation

This paragraph focuses on the allocation and water distribution at scheme level. The Dodota irrigation scheme is a controlled scheme with upstream controlled vertical slide gates. This makes it possible to allocate the water very specifically. Regarding the National Water Policy summarized in Box 4.4, the management of water resources should ensure social equity, system reliability and sustainability. The Water Policy refers to actions of the government at various levels and in various branches affecting the development, management and allocation of water resources. The question rises, how for the irrigation scheme the distribution of water among users should be arranged. In interviews with government officials, it was not clear how this water distribution should take place, and how to decide upon this matter. However in the National Water Policy, is also directed how water should be allocated and apportioned, this is shown in Box 4.10 .

Box 4.10: Directives of the Water Policy (MOWR, 2004)

- *The basic minimum requirement for basic human and livestock needs as well as environment reserve has the highest priority in any water allocation plan;*
- *Water allocation gives the highest priority to water supply and sanitation, while apportioning the rest for uses and users that result in highest socio-economic benefits;*
- *Encouragement of water allocation need to be based on efficient use of water allocation ,which is based on efficient use of water resources that harmonizes greater economic and social benefits;*
- *Water allocation shall be based on the basin, sub-basin, and other hydrological boundaries and take into considerations the needs of drought prone areas;*
- *Adopting the principle that water allocations shall not be made on permanent basis, but rather on agreed time horizon that fits best with the socio-economic development plans.*

The principles shown in Box 4.10 are important for the management of the irrigation scheme. The first point of the National Water Policy focuses on the water use priority. Irrigation is the third priority for the allocation of water, after water supply for livestock. The environment is after the hydropower and industrial water supply the 6th priority. This underlines the water division which was intended for the headworks. In case of a low stream in the Boru river this can be entirely diverted for irrigation. Furthermore, three other important points are coming forward regarding the allocation which can be related to the Dodota irrigation scheme. The objective of the scheme is to assure food self sufficiency, this is completely in line with the third point of the policy, to support economic and social benefits. The fourth directive focuses on the boundaries for water allocation. The Dodota scheme will be managed by WAUs which are organised according to the administrative boundaries of the PAs and according to the layout of the scheme with branch canals. Besides this setup, the policy considers special attention for drought prone areas and gives them a higher priority. In this sense, it should be considered within the scheme, which areas are most in need of irrigation water. An issue here would be how to assess the command areas of the different WUAs and determine a priority based on drought proneness. Another approach, which is used here later on, is to use social data of the SNP program to indicate the areas in which farmers have most trouble, to achieve food-self sufficiency. Based on the population density and given food aid it was possible to identify the most food insecure areas. To meet the National Water Policy, allocation could be prioritised based on this information as shown in Figure 4.16. It must be said that the primary objective of the SNP program is to move away from the project area, because hopefully farmers are food self-sufficient in the future. In this case the priority of allocation should be adapted to other criteria. This as also confirmed in the last policy which underlines that the allocation is not on a permanent base.

To determine the allocation priorities shown in Figure 4.16 many different sources of information were required. Geographical information was retrieved from the ARDO, Education bureau and the OWWDSE. With this information it was possible to show the scheme with the hydrological boundaries and the administrative boundaries. To have a clear overview of the social statistics of the command area, specific information was required. Data from the different *kebele* concerning the "total population" and the number of "Food-aid" beneficiaries in a *kebele* were retrieved from the ARDO and WRDO respectively. Also information from the PAs was available, concerning the "local population" receiving irrigation from a certain branch canal. With this information together it was possible to have an interpretation of the need for the SNP program according to WUA command areas. Based on this information an allocation priority can be determined based on a total ratio. The calculation of the ratios is based on three variables; the "local population", "total population" and the number of "food-aid" beneficiaries. To calculate the total ratio, the following equation 4.1 is used to describe the relation between the variables given in Table 4.4.

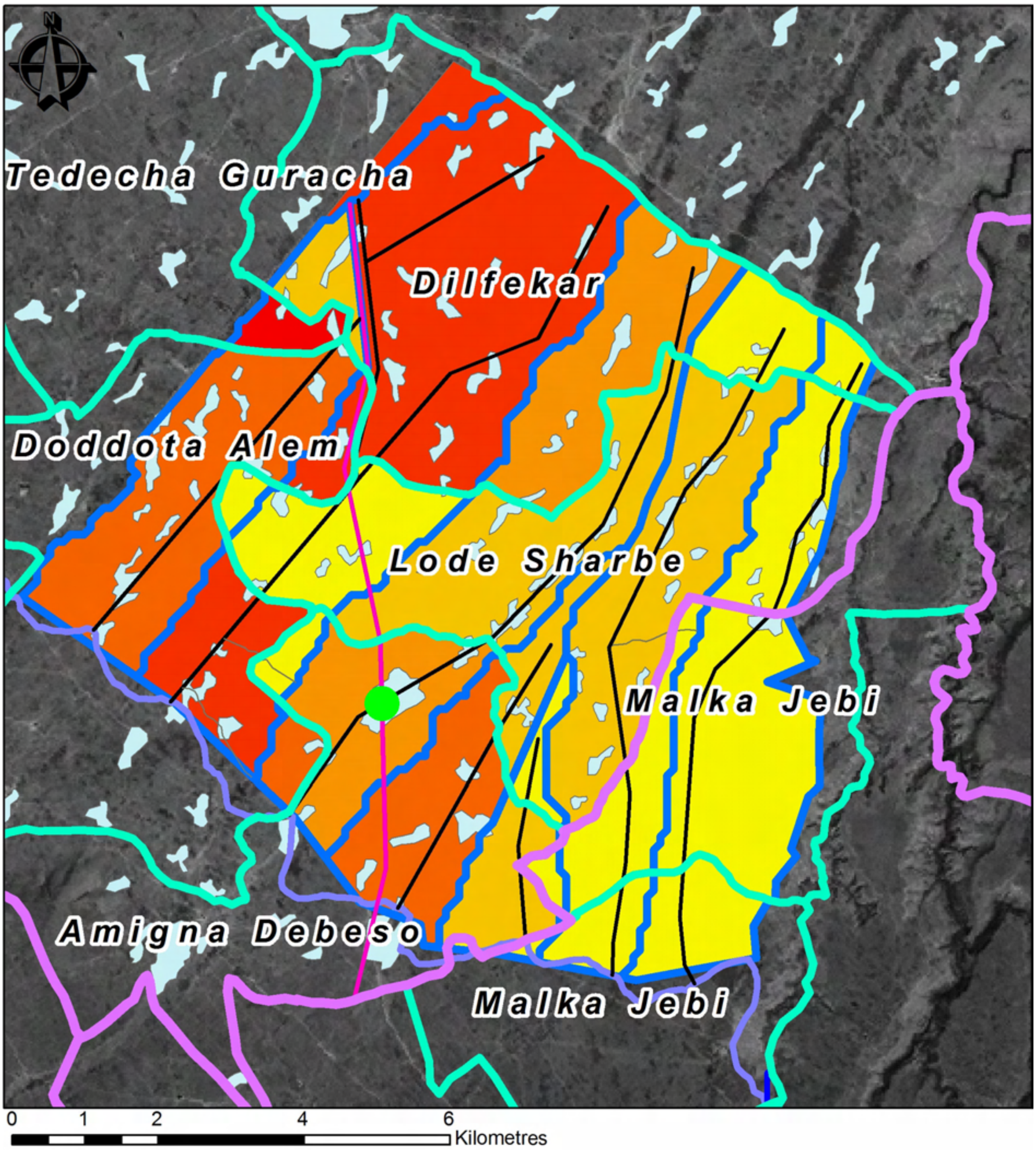
$$\textit{Total ratio} = \left\langle \frac{\textit{local population}}{\textit{total population}} \right\rangle x \left\langle \frac{\textit{food-aid}}{\textit{total population}} \right\rangle \qquad \text{(eq. 4.1)}$$

Table 4.4: Relation between variables

Variables	*Higher (input)*	*Lower (input)*
Local population	> → >	< → <
Total population	> → <	< → >
Food aid	> → >	< → <

The complete table with all information and the calculations is shown in APPENDIX 3. For some areas, data of the local population was missing. For this reason it was not possible to determine the "total ratio" for these areas. However in general it is possible to determine the priorities of allocation for the tertiary units. The total area of the scheme covers almost 9000ha, more than half of this area is planned for irrigation. From Figure 4.16 the following order can be obtained starting from branch canal 1[34] ; the allocation priority in this case could be branch canal 6, 7, 4, 5, 3, 2 and 1. Also several interviews underlined and indicated Dilfekar as a food unsecure area. As seen on the map the branch canals are divided according to administrative boundaries. This implies that a WUA of a single branch canal is covering several administrative boundaries. However as indicated on the map, the need for the SNP within this administrative boundaries can be different as well. Again also here interviews confirmed that as an example the middle part of branch canal two was more drought prone than the beginning and end of the branch canal. These differences could be fine tuned and allocation could be organised to even meet this variation. For the Dodota irrigation system the collective decision-making about system management and direction, and thus also the allocation and distribution to the different branch canals is decided by the head organisation, the Management District Board. Together with the OWWCE and the WUAs this management board must figure out how the allocation in the scheme should be arranged, to meet the National Water Policy and to serve the area in the best way.

[34] Closest to the headworks.



Branch canal	Total area (ha)	Planned irrigation area (ha)
1	1241	258
2	1411	599
3	335	128,5
4	617	568,75
5	1787	1057,75
6	2373	1643,25
7	1095	508,75
Total	8859	4764

Figure 4.16: The Dodota irrigation scheme with a priority for allocation (ArcGis 9.2)

4.4 Conclusion

This chapter used the three dimensions of Uphoff explained in Pant (2000 p.16) to describe the irrigation management activities. The control activities described the importance of the design and infrastructure. The design is sophisticated and the system deals with erosion, sedimentation and natural drainages and even allows water distribution with upstream control. However the same design makes it impossible to be managed by the farmers only, since it requires heavy machinery and skills for the operation and maintenance. The ′technology′ requires a strong organisation. For the Dodota scheme, based on the spatial dimension of the scheme, the organisational activities have been divided; the government will manage at scheme level and the WUA at field level. These forms of organisations need to contribute significantly and are both responsible for proper management to enable efficient and fair irrigation. The management of the OWWCE and the WUAs cannot be seen apart from one another and in the District Board of Management decision making about the water distribution for the scheme is arranged. For the establishment of irrigation, water rights and land rights at national level, regional level and local level are closely interrelated. With the introduction of the new scheme, local water rights are newly introduced. It appears that there are some basic rules necessary to arrange the water use activities amongst the farmers. At field level the WUA needs to establish community participation for which appropriate incentive structures, fines and enforcements of rules are required. So far it can be concluded that not all rules are considered, and for the future these need to be improved to avoid future conflicts, especially concerning the depth and frequency of irrigation. Besides the rules which are required at field level, also rules are required at scheme level. Also here it appears that rules are missing, especially concerning the proportion of the flow going to different branches and the sequence in which command areas are watered. Theses allocation rules are of major importance to establish fair and efficient distribution. Moreover it has turned out that the command area is characterized by differences in food insecurity indicating drought prone areas, most severe drought prone areas are in the tail end of the system. For the management at scheme level the National Water Policy has given some directives how to organise the allocation and apportionment. To achieve fair and equitable distribution it is required to implement the allocation rules. So far these directives have not been implemented yet, but need to be taken into consideration by the Management Board of Districts.

5 IRRIGATION PRACTICES AND LIVELIHOOD OF FARMERS

This chapter focuses on the social effects of the Dodota irrigation scheme. Here the objective of the government was to improve the status of farmers and support them to be food-self sufficient. To do so also farmers need to adapt to new practices to improve their production. The first section focuses on the current situation of farmers in the study area, particularly the village Amigna Debaso and describes which processes needing to take place and are going on within the farming community. The new developments lead to upcoming changes in cultivation, conservation practices and production and are discussed in the second, third and fourth section respectively. Section 4 also begins with a preliminary study of the CWR to have an idea about the water demands. In the last section the study enfolds how current assets are being developed and how this can lead to strategies for actually changing livelihoods.

5.1 Agrarian conditions and relations

With the introduction of the new irrigation system, the farming community has to change too. Before, the farming community was mainly organised within the Peasant Association based on a government structure. For agricultural activities farmers were supported with several extension services from the local Development Agents and the ARDO as discussed in §3.3. Many farmers in the project area were not food-self sufficient and have been supported by the SNP for more than 25 years. This fact is not to be underestimated, as the dependency and limitations in the livelihood of farmers has created a certain culture or mind set. From interviews it became clear how farmers have been putting themselves together, to prepare their fields, with the knowledge that it most likely would not bring them any production or very little. This is not only very sad, but made the farmers also not motivated to work on their fields anymore, though there were not many other options. With the introduction of irrigation to the area, this was not easy to overcome, especially because farmers did not understand what irrigation could bring to them and whether it would actually work. This was also due to the fact that the implementation of the irrigation scheme was planned solely by the government and farmers were not involved in the planning and design process. Interviews with the engineers in Box 5.1 illustrated how the farmers did not care about their own situation and were even reluctant to contribute to the system because it was considered as a threat to their current livelihood.

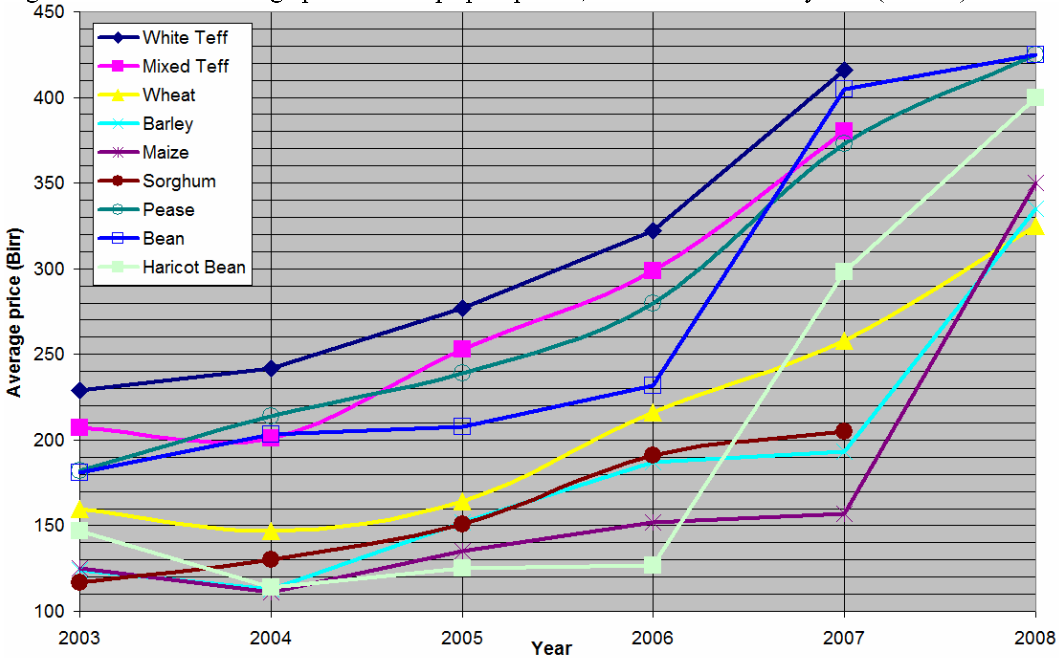
Box 5.1: Illustration of interviews with engineers

When we were working in the fields we had a lot of contact with the farmers "Once upon a time a farmer said "It doesn't matter if it rains here, as long as it rains in Canada!". Farmers were unwilling to use the water from the irrigation canals last year. They were used to food aid and therefore didn't want to use irrigation, it would prevent them from getting food aid in the future and they were accustomed to this. However after threats by higher officials, convincing them they had to use irrigation, they eventually start using it. First they were reluctant to use water and were not confident in the system. Now the farmers can not wait to use it and to improve their yields.

Farmers were initially not convinced that the irrigation system could support them. In this sense the irrigation term of last year was very important to actually show the farmers that the irrigation system can work and can provide additional water to their plots. The farmers who have received irrigation, have trust that the new irrigation system will bring them irrigation water in the future as well. They are eager to use this water and want to become independent from food aid instead. They also showed to other farmers that the system does function and can support them too. Nevertheless this doesn't apply to all farmers in the area because some farmer representatives placed guards to prevent farmers from damaging the system. In this situation they were afraid that some farmers did not trust the system, but so far no damage has been reported. In its turn, this shows that farmers have trust in the system.

Another important issue for now and in the future is whether farmers are also willing to invest, contribute and participate in the system. Until now preparation works have been initiated, coordinated and controlled with the support of the SNP program. In the future the farmers will have to organise the operation and maintenance in the WUAs. But also here the farmers will be supported by the government extension service and thus with the involvement of the ARDO and the CPCB. These services are not only related to support irrigation but are going much further as shown before. Nevertheless the farmers will be responsible for their own way of managing their fields. Here lies one of the major challenges for the extension services to support the farmers and for the farmers to make optimal use of the opportunities given to them to improve their livelihood. Farmers are responsible for running their own business and are making their own decisions on what crops to grow and which agricultural technologies to use. In general farmers use local varieties adapted to the local agro-climatic conditions. Crops are grown to meet the families' basic food requirements and to be sold at the market for profit. The decision for crops is closely related to local market prices. Dhera is the closest market to the project area and the annual average prices of most important crops are shown in Figure 5.1. Especially last two years, food prices increased tremendously because of shortages (The prices of 2008 have been estimated but not for all crops). In the project area there are some cash crops like the haricot beans which is very known, the price of this crop particular has increased very fast as can be seen in the figure. This convinced farmers in the project area to grow haricot beans as well.

Figure 5.1: Annual average prices of crops per quintal, Dhera market survey data (ARDO)



If too many farmers grow the same crop and the total production is high, prices can fall, like was seen locally last year with green peppers (not included in the figure). Therefore farmers prefer to spread the risks and grow several crops instead. In interviews, farmers explained that they changed crops often related to market prices. In consideration to the use of agricultural technologies to increase production, farmers are reluctant, since most production suffered or failed due to a lack of water. In the area fertiliser (DAP and UREA) and improved seeds were available but in very limited use, chemicals (pesticide and fungicides etc.) were not available (Aman et al, 2006). The adaptation of new agricultural technology at household level is according to Teshome (2003) based on the access to resources and the perceived benefits. Here farmers consider several factors, like the price, labour and time required, the yield anticipated and available water. If irrigation water can be delivered, it is not unlikely that many farmers are more interested in these technologies, which could improve the production significantly. This is also more likely with the establishment of the cooperatives. Until now farmers were unable to obtain credits from banks or financial institutions because land was not recognised as collateral. When the cooperatives are established, they can grant the farmers credit to invest in their lands and inputs to increase their production. The new irrigation technology and the supporting institutions give the farmers access to not only water resources but also financial resources to improve their livelihood. Unfortunately the development of agricultural activities will put pressure on the available water resources as more irrigation water will be required with increased production by new technologies. Thus the individual choices of farmers have a major impact for the irrigation requirements in the tertiary units, the branch canals and for the scheme as a whole and are therefore important to be considered.

5.2 Cultivation practices

Before the implementation of the irrigation system farmers were completely dependent on rainfed agriculture. With the introduction of the irrigation system the livelihood of farmers is intended to be changed. In the project area, it is intended by the ARDO not to only change the cropping pattern, but to also change the crop intensity. The setup of the cropping pattern is based on information obtained from agronomists. Based on their experience a new cropping pattern is composed, mainly based on two groups of crops; fully irrigated crops and supplemental irrigated crops. In the *belg* season from January to May farmers were unlikely to grow crops because of a high risk of insufficient rain. With the irrigation system, these crops could depend on irrigation instead. The dry crops which can be interesting to grow here are mainly maize and sorghum. For the *keremt* season, crops can be rainfed and supplemented with irrigation. Here more crops are selected such as; wheat, onion, pepper, haricot bean etc., and also maize and sorghum. However currently these plans have not been worked out and planned yet and only single crop seasons will be established. So for this there are many constraints to overcome in the current land use, such as the separation and division of plots, the crop choices and the planning of land preparation. According to Rahmato (2004), peasant themselves frequently prefer plots in different locations or of different quality. This is also seen in the project area, but next to this, farmers have divided their plots in even smaller pieces to be able to produce several different crops. Important for them is that the crops can be used for home consumption, for forage of cattle, or sold at the market. Farmers are making the crop decision by themselves but in interviews it became apparent that they are willing to change and adapt. In other nearby irrigated areas it is seen that farmers narrow down the selection to a few crops only. In this way a higher production can be obtained and sold at the local markets. Another constraint for achieving higher production is the planning which can be undermined. For this year the preparation for irrigation was planned and executed in February and March, more or less according to schedule. However the preparation of the fields for sowing in May, needed to be finished before half of April. Unfortunately due to a lack of rainfall in March and April, farmers were not able to prepare their plots and unable to sow. This shows that the current planning in the new irrigation scheme, is still heavily dependent on rainfall. The current farm techniques make it impossible for the local farmers to plough the fields. The oxen are not strong enough to cut through the dry crusted fields, but with one or two days of rain the fields can be easily ploughed as seen in Figure 5.2 and the fields can be prepared within a week. Farmers explained that good field preparation takes 3 to 4 ploughings.

Figure 5.2: Farmer ploughing

5.3 Soil and water conservation

Interviews with the farmers, observations and secondary data showed that farmers were not using soil and water conservation practices. Moreover they showed how current cultivation practices lead to severe land degradation and land erosion. Farmers in the project area are under pressure to cultivate their fields for their livelihood and also to claim their support[35] for food for work. Fields are used every year and practices such as fallowing are uncommon (Aman et al, 2006). But fields are not given additional agricultural inputs, since farmers are not able to afford such investment and are reluctant in relation to the lack of water. Another reason of land degradation is the use of agricultural land in combination with grazing land. Currently, after the cultivation season, all fields are used as free grazing areas and the cattle is fed with crop residues. It is likely that the irrigation scheme will negatively effect free grazing, due to changed cropping patterns. Fodder will become a much more important crop with limited free grazing. Another cause of land degradation which is observed is that manure is not used to fertilize the agricultural fields, but sold or used for domestic purpose, such as cooking, fuel and house warming. A result of free grazing is bare land cover and this makes the land suffering from severe wind erosion, which is even worsened by ploughing. But farmers are not protecting the top soil by strip cropping or other conservation measures. With regards to water saving practices it is very much the same. Unfortunately practices such as ‘no tillage’ ‘primary tillage’ and ‘mulching’ are not used. Especially the first method could improve the soil’s organic material, and protect against erosion and evaporation, but vegetation cover is currently removed by cattle. With ‘primary tillage’, the fields are ploughed before the first irrigation takes place. The mostly hard and compacted soil is broken which allows floodwater to infiltrate quickly before it is lost by evaporation or drainage. This could be an interesting practice for the farmers, and would be a great advantage if farmers were able to plough their dry fields and make use of ‘primary tillage’ for the preparation of their fields. This year it was seen that irrigation canals were full of water, but not being used, because farmers waited for rain to prepare their fields as mentioned earlier. ‘Mulching’ is very useful to conserve the soil moisture after being fully irrigated, ploughed and sowed. It is used in Eritrea and called *Mekemet* which means ‘we sealed it’ and minimizes the evaporation (Haile, 2007). During this practice the farmers stands on a flat wooden plate pulled by a pair of oxen. The soil is broken in smaller pieces, compacted and the surface is covered with a thin layer of fine soil. This practice could be considered for the project area if there are considerably long irrigation intervals and evaporation needs to be minimized.

5.4 Soil characteristics and irrigation requirements

The irrigation application and intervals are very important to assure crops with sufficient soil moisture. For spate irrigation water needs to be retained in the soil to enable crops to grow. The previous paragraph discussed how farmers are distributing water. Here for it is important to have an idea about how much water is required for sufficient irrigation and how much water can be stored. Also the time of applying irrigation can make a difference and can differentiate between before and or during the growth season, this is studied more in detail in the next chapter. As seen in the study area it was not clear to the farmers how long and how much water to apply to their fields. This depends on the properties of the soil and the crops. The following soil parameters (17.1% sand, 39.9% clay and 43.0% silt) were collected by Kebebew and Mengistu (2007). Based on the USDA soil texture triangle[36] shown in APPENDIX 4 the ‘silty clay loam’ texture has been indicated. Hereby it appeared that the soil is mostly related to ‘silty clay’ and therefore the soil properties of ‘silty clay’ are used from Table 5.1 of the FAO.

[35] Farmers within the SNP are supported with the condition that they did not manage to be food-self sufficient.
[36] U.S. Department of Agriculture developed a textural classification in a triangle.

Table 5.1: Indication of the soil moisture constants and physical properties (FAO)

IDD	Soil Texture and Available Water							
Class	Soil Properties	Field Capacity (mm/m)	Wilting Point (mm/m)	AM (mm/m)	Ratio AM/RAM	RAM (mm/m)	Bulk Density (g/m³)	Total Pore Space (% volume)
Sandy	Average	150	70	80	0,7	55	1,65	38
	Range	100-200	40-100	60-100		45-70	1,55-1,75	36-40
Loamy Sand	Average	180	80	100	0,7	70	1,6	40
	Average	130-230	50-110	70-130		50-90	1,50-1,70	38-42
Sandy Loam	Range	210	90	120	0,65	80	1,5	43
	Average	150-270	60-120	90-150		60-100	1,40-1,60	41-45
Loam	Average	310	140	170	0,6	100	1,4	47
	Range	250-360	110-170	140-200		85-120	1,30-1,50	45-49
Clay Loam	Average	360	170	190	0,55	105	1,35	49
	Average	310-410	150-200	160-220		90-120	1,25-1,45	47-51
Silty Clay	Range	400	190	210	0,55	110	1,3	51
	Average	350-460	170-230	180-230		100-125	1,20-1,40	49-53
Clay Loam	Average	440	210	230	0,5	115	1,25	53
	Range	390-490	190-240	200-250		100-125	1,20-1,30	50-55

Another parameter, the bulk density of 1,26 g/cm^3 obtained by Kebebew and Mengistu (2007) is also in line with the indications on Table 5.1 of 'silty clay' with a range of 1,20-1,40 g/cm^3. Using the soil particle density (2,650 kg m^{-3}) and the measured bulk density, the saturation water content can be calculated. If the soil is saturated all the pore space is filled up with water, thus the saturation water content is equal to the porosity seen in equation 5.1:

$$\theta_{sat} = 100\ (1 - \rho_b / \rho_p) \qquad \text{(eq 5.1)}$$

Where θ_{sat} = soil water content at saturation point (*vol%)*
ρ_b = soil bulk density (g/cm^3)
ρ_p = soil particle density (g/cm^3)

The saturation water content is approximately 52% volume. This exists in the upper soil layers immediately after a heavy rainfall or irrigation. However this is not the field capacity because the soil matrix drains freely under gravity. The field capacity (θ_{FC}) is much lower and Table 5.1 shows an average of 40% volume or 400 (mm/m). For plants it is easy to extract water at field capacity but if the water in the soil decreases, the remaining water is more difficult to extract. At the wilting point the plant can no longer extract water in sufficient quantities (Dries and Gerbrandy, 2006). The total available soil moisture for the plant is between the field capacity and the permanent wilting point (θ_{WP}). This relation is given in equation 5.2:

$$S_a = 10\ (\theta_{FC} - \theta_{WP}) \qquad \text{(eq 5.2)}$$

Where θ_{FC} = Field capacity (*vol%)*
θ_{WP} = Permanent wilting point (*vol%)*
S_a = available soil moisture (mm/m)

The magnitude of the total available moisture is a function of the soil texture and structure and indicates the capacity of the soil to have water extracted by the plant. As seen in Table 5.1 the soil in the project area has a rather high S_a or AM, which indicates that a relative lower frequency of irrigation is required. Though, at the end this is also depending on the crop water requirements and the root depth. The Total Available soil Moisture (TAM) is the total amount of water a crop can extract from its root zone (D) given by equation 5.3:

$$\mathbf{TAM = D.S_a} \quad \text{(eq 5.3)}$$

Where D = root depth (m)
S_a = available soil moisture (mm(water)/m(soil depth)
TAM = Total Available soil Moisture (mm)

Before the wilting point is reached a plant is already suffering from water stress[37]. The Readily Available soil Moisture (RAM) uses the fraction (p)[38] of the total S_a that can be safely removed before stress occurs, given by equation 5.4:

$$\mathbf{RAM = p.TAM} \quad \text{(eq 5.4)}$$

Where p = depletion factor
TAM = Total Available soil Moisture (mm)
RAM = Readily Available soil Moisture (mm)

In Table 5.1 a depletion factor of 0.55 has been determined to avoid water stress. For the calculation of the irrigation intervals (Int) in the project area the RAM is calculated for the different crops to show preferable and necessary irrigation intervals. Needed for these calculations are the crop water requirements shown in equation 5.5:

$$\mathbf{Et_{crop} = k_c.ET_0} \quad \text{(eq 5.5)}$$

Where K_c = varies with crop and stage
ET_0= reference crop (mm/day)
ET_{crop} = crop evapotranspiration (mm/day)

For the determination of the irrigation interval (I_{int}) it is calculated how long it takes the specific crop (ET_{crop}) to utilise the RAM or TAM. In this way the soil properties are combined with the specific crop water requirements, this is shown in Equation 5.6:

$$\mathbf{I_{int} = RAM/ ET_{crop}} \quad \text{(eq 5.6)}$$

Where TAM = Total Available soil Moisture (mm)
ET_{crop} = crop evapotranspiration (mm/day)
I_{int} = Irrigation interval (days)

The net irrigation requirements are calculated by filling the soil up to field capacity again. If the TAM or RAM is almost reached it is clear that irrigation is required. To irrigate up to field capacity the application efficiency has to be considered too. The gross irrigation depth is thus much higher, see equation 5.7 and 5.8:

$$\mathbf{I_{net} = I_{int} * ET_{crop}} \quad \text{(eq 5.7)}$$

$$\mathbf{I_{gross} = 1/ef * I_{net}} \quad \text{(eq 5.8)}$$

[37] With increasing water stress yields start to decrease and the plant can start wilting. In this case $ET_{act} = ET_{crop}$ (Actual evapotranspiration = Crop evapotranspiration).
[38] The magnitude of the depletion factor is decided for each crop in a given soil.

Where I_{net} = net irrigation requirements (mm)
I_{gross} = gross irrigation depth(mm)
e_f = field application efficiency

The calculation of irrigation requirements of the crops grown in the project is shown in Table 5.2. For the calculation the highest value of ET_0 in the command area is used from Table 3.1 namely 4.4 mm/day. The input data of several crops is shown in APPENDIX 5, from where the highest K_c values are selected from the different growth stages and the shortest root depths. In this way is calculated, under the most severe situations what the irrigation interval and amount should be, to protect the crop from water stress. Table 5.2 shows that the cereals are most drought resistant, though teff has relatively a short irrigation interval. The beans, onions and pepper are most sensitive to drought and require a frequent irrigation turn. Even though only the RAM is considered for the calculation and the crops are not wilting yet, it is doubtful whether the spate irrigation system can meet these requirements. The I_{net} irrigation requirements in Table 5.1 seems low, but it should not be forgotten that the application efficiency at field level losses may range between 15 to 50%, so I_{gross} can be twice I_{net} (Meijer, 1990). Halcrow in Tesfari (2001 p.20) estimated losses of 50% for the field application in traditional spate irrigation systems. Therefore the same efficiency will be used for the Dodota scheme. Thus to irrigate maize up to the field level capacity, 252 mm water needs to be applied. For a single hectare of maize is thus 2520m^3 of irrigation water required, which with a main d'eau of 50 l/s will take more or less 14 hours.

Table 5.2: Different crops with calculations for the I_{int}, I_{net} and I_{gross}

Crops	Names	k_c	Et_{crop} (mm/day)	S_a (mm/m)	D (m)	p	TAM (mm)	RAM (mm)	I_{int} (days)	I_{net} (mm)	I_{gross} (mm)
Cereals	Maize	1,1	4,84	210	1	0,6	210	126	26	125,8	251,7
	Sorghum	1,05	4,62	210	1	0,55	210	115,5	25	115,5	231,0
	Barley	1,15	5,06	210	1	0,55*	210	115,5	22	111,3	222,6
	Wheat	1,15	5,06	210	1	0,55	210	115,5	22	111,3	222,6
	Teff	1,1	4,84	210	0,5	0,55*	105	57,75	11	53,2	106,5
Oil and protein crops	Pease	1,15	5,06	210	1	0,4	210	84	16	81,0	161,9
	Bean	1,15	5,06	210	0,3	0,6	63	37,8	7	35,4	70,8
Vegetable crops	Onion	1,05	4,62	210	0,3	0,25	63	15,75	3	13,9	27,7
	Pepper	1,15	5,06	210	0,5	0,25	105	26,25	5	25,3	50,6
	Tomato	1,15	5,06	210	0,7	0,4	147	58,8	11	55,7	111,3

* The information of fraction (p) was missing, used here is the ratio AM/RAM from Table 5.1

5.5 Production and yields

The main objective of the spate irrigation system is to improve the food-self sufficiency of the farmers. With the irrigation facilities additional water can be supplied to increase yields, even when it is already clear that according to Lawrence and van Steenbergen (2005) the yields of most spate-irrigated crops are low. Farmers explained in interviews how in some 'bad years' they were not able to produce any crop, or only able to grow fodder. The agricultural production suffered from a lack of water. The actual impact of spate-irrigation is hard to define, but in the small irrigation trial of last year, significant changes in production have already been observed. As mentioned before, also farmers in the area were enthusiastic about the impact of irrigation on the yields. The irrigation specialist Kebebew and Mengistu (2007) have collected information from the DA of last year. Hereby data was collected of several farmers about; plot sizes, crops, sowing dates, amounts of irrigation turns and yields. The same information was collected from several farmers who did not receive any irrigation. Their study made it possible to compare the production with the current agronomic practices with and without irrigation and.

Table 5.3: Irrigation of 2007 with local average yields of major crops

Year Crops	2007 Irrigated (Qt/ha)	2007 Non Irrigated (Qt/ha)	2006* Good Year (Qt/ha)	2005* Normal (Qt/ha)	FAO (t/ha)
Wheat	13	4,5	20	12	4 to 6
Barley	26,1	7,1	20	12	-
Maize	32,4	8,3	12	8	6 to 9
Teff	7,5	3,4	6	5	-
Haricot Bean	15,3	6,3	4	4	1.5 to 2

* Average crop yields in quintals (Qt = 50 kg) [39] , PA Amigna Debeso, obtained from DA

Table 5.3 shows interesting results of this study. It appears that despite the lack of fertiliser, pest control, crop rotation or improved farming practices yields are significantly improved but still remain very low if compared to the yields given by the FAO (2008) of good commercial yields. These results are of course not expected[40] since the objective is to achieve food-self sufficiency. The difference with non irrigated crops in 2007 varies between 2 or 4 times higher yields. The production was overall much better than in normal years and also even better compared to the good year of 2006. Here it is seen that only wheat was considerably low. The wheat most likely has been severely suffering from water stress as irrigation was given late. Also the production of teff could possibly be suffering of water stress since, also in Table 5.1 it is indicated to require a relative short irrigation interval. The other crops barley, maize and haricot bean, are giving much higher yields, especially the haricot bean, this can contribute to the income of farmers. This will not only benefit the farmers themselves, but will also give employment and market development. With investments in agronomic practices and proper irrigation, it is likely that higher yields can be expected for the future.

5.6 Transforming livelihoods

For more than 25 years the project area is supported by food aid and currently under the Safety Net Programme. The general conditions of housing and services within the villages lack of basic amenities such as potable water, sanitation, electricity and health care. The farmers are a vulnerable group and are chronically dependent on public support. With traditional farm practices and livestock keeping farmers intend to produce for domestic use and for the local markets. The co-existence of livestock keeping and agriculture is the main cooping strategy and according to Lawrence and van Steenbergen (2005) almost universal in spate irrigation areas. The livestock contributes to the household in varies way, as provision of draught power, transport and production of products for consumption. With the unreliability of spates in many systems farmers need to rely on other sources to cope with uncertainties. For this reason the farmers are interested in investing in cattle, because cattle can be sold to overcome difficult times. Also in interviews farmers explained, that if they would have extra income from agriculture, they would positively consider buying more cattle for saving financial capital.

The irrigation system is intended to have a social impact and to change the livelihoods of farmers. Currently as described the farmers are vulnerable and their assets are poorly developed. With the introduction of the new irrigation scheme possible new opportunities are given to farmers. Therefore transforming structures need to be in place with processes to give possibilities to farmers to change their livelihood strategies and improve their assets. These transforming structures involved in the scheme management and the extension services of the government and the processes are already discussed before. But until now it is not shown directly or indirectly how structures and processes influence and give access to the different

[39] 2*10 quintals = 1 ton (Teshome, 2003 p.144).
[40] Expected or comparable yields of similar systems and crops were unavailable.

assets and how they are interrelated. The 'human capital' represents the skills, knowledge, ability to labour and good health (DFID, 1999) and here it is observed that the farmers are using limited traditional farm practices and are not motivated. After the irrigation trial of 2007 farmers were enthusiastic and willing to use irrigation. With training and guiding they could improve their methods and this could be supported by the extension services of the ARDO. Also in relation to social resources, changes are ongoing with the CPCP with the establishment of the WUAs and cooperatives in the future. 'Social capital' refers to networks and connectedness to increase people's trust and ability to cooperate and or the membership in more formalised groups. In these new organisations farmers are members and participate according to a system of rules, norms and sanctions. In this way operation, maintenance and fair water distribution will be arranged to make optimal use of the natural resource. Especially in the project area the livelihoods of farmers are mainly reliant on natural-resource based activities. The 'natural capital' makes it possible to derive resource flows useful for the livelihood. Farmers are given access to land with user rights and to irrigation with water rights. The latter can be arranged within the WUAs. With the additional supplemental irrigation production can be increased. This would not have been possible without the construction of the irrigation system, which is considered 'physical capital' and is required to facilitate the water supply. But besides the system also improvements for infrastructure are being established, to facilitate the transportation in order to improve market access. The last capital is 'financial capital' and can be converted in either one of the other assets, or combinations of assets. In this way credits and loans can lead to changes in the other capitals and this can improve directly or indirectly the livelihood. Table 5.4 shows the importance to understand which possible strategies farmers intend to follow, to improve their livelihood. It is clear that the government is trying to support the farmers, but eventually it is the farmers who are making the choices. The farmers need to be convinced or have trust in the functioning of the irrigation system to actually make it work and improve their livelihood.

Table 5.4: Indication of the transformation of livelihood in the project area

Current Assets	Transforming Structures	Transforming Processes	Future Assets	Livelihood Strategies
Human: -Deprived to produce -Careless -Underemployment	ARDO – Education (training)	-Knowledge and skills	-Improved skills and application -Improved health -Job opportunities	Farmers are motivated and encouraged to grow new crops and intensify production
Social: -Organised in PA	CPCP establish WUA/Cooperatives	-Organised Water user groups -Water rights and obligations	Membership formalised group (rules, norms, sanctions)	Farmers participate in the maintenance and operation (contribute labour) and have a responsibility and a sense of ownership
Natural: -Access to land* -Low production	-ODPPC - OWRB-OWWDSE-OWWCE Spate Irrigation System	Increase water Availability	-Access to irrigated land -Higher production	Farmers increase their production
Physical: -Poor transport -No irrigation facilities	-Road Authority -ODPPC – OWRB-OWWDSE-OWWCE Spate Irrigation System	-Infrastructural development -Access to supplemental irrigation	-Improved transportation -Supplemental irrigation system	Farmers use the irrigation system effective and use the infrastructure.
Financial: -Food insecure -Some Livestock	Cooperatives	-Access to credits and loans	- Government support -Cash for Investments -Access to other markets	Farmers invest in their productivity and other assets.

* Not all farmers have there own land (User right)

5.7 Livelihood strategies

According to Kollmair and Gamper (2002:8) the livelihood strategies comprise; ”the range of combination of activities and choices that people undertake in order to achieve their livelihood goals”. In interviews with farmers it was difficult to discuss the livelihood goals. First of all, their situation of living as described before is not that great and it is understandable that they would like to improve. Also it is logical that they would like to have houses in the city and cars etc. But at the same time they see this also as a dream, and there is nothing wrong with dreaming, but that doesn’t make for realistic livelihood goals. Besides dreaming, most farmers simply replied that they would like to be food-self sufficient and to see how things develop. In general farmers were very positive about the developments so far and were looking forward as well. From this perspective, though in an early stage it is possible to indicate some possible directions. Given the efforts of the governments and their plans, a livelihood strategy of farmers is to ‘adapt to the irrigation system’ and use irrigation with proper farming practices. They will increase the production by using irrigation as explained. In a later stage farmers could ‘invest in agronomic technology’ and agronomic practices, such as crop rotation, intercropping and soil and water conservation. Another option would be to ‘invest in livestock’. One of the issues already discussed before with livestock is the need for grazing areas or fodder. Most likely with the new irrigation scheme there will be less grazing area, thus more attention must be given to fodder. Another strategy is based on economic development. Given the introduction of the irrigation system and increased production, it can be assumed that new job opportunities could be created as a growth that may emerge around services and marketing. In other spate areas it is seen that ‘diversification’ is a strategy to assure an additional income besides farming. Here farmers are working as labourers for off farm activities, or may be engaged in business, trade, transport or small scale production and sale (Lawrence and van Steenbergen, 2005). Another strategy important for the project area to be considered is ‘migration’, because as explained with the introduction of the user rights, farmers are able to sub rent their plots. Because of irrigation facilities, the rents will be much higher and this could give farmers maybe enough certainties to go somewhere else. The oppose effect is that landless people in the area are given opportunities to rent land and to start with ‘agricultural business’. Besides developments which encourage the local economy and the optimal use of the irrigation system there could also be negative effects. This could occur if besides the use of the irrigation scheme additional water resources are being used, like groundwater or drainage water, with the use of pumps. This increase of the use of groundwater is considered a threat by Lawrence and van Steenbergen (2005:88) and is one of the causes in decline of spate systems. The ‘implementation of water technology’ can undermine the ‘critical mass’ and harm the community participation in the WUAs.

Livelihood strategies:

- *Adaptation irrigation*
- *Adaptation agronomic technology*
- *Livestock Investment*
- *Agricultural business*
- *Diversification*
- *Migration*
- *Implementation water technology*

5.8 Conclusion

This chapter has shown that the development of an irrigation scheme does not end with its construction, this is only the beginning. The follow up is supported and guided by the government with several extension services. The transforming structures and processes are needed to operate at all levels and are of central importance for access to capitals, exchanges between different types of capital and the returns to any given livelihood. The main objective or livelihood outcome of the government is to improve the food security and thus to improve agricultural production, which will give farmers new opportunities to choose strategies to improve their current assets. The farmers' first objective is to also achieve food-self sufficiency and they hope for more. For all these ways the development of assets are critical to improve local livelihoods. However, this development and improvement of assets is directly and indirectly dependent on actually receiving irrigation. This shows the importance of the structures and processes to adapt the role of the farmers to the irrigation system and to achieve community participation. It has been shown that most farmers are willing and motivated to cooperate, but at the same time their cultivation practices are lacking behind and institutions are very underdeveloped. The development of irrigation is hereby limited to the abilities of the farmers. Also the structures being proposed seem rather coercive in management styles. Thus not only the role of the farmers needs to be adapted to the irrigation system but also the role of the transforming structures and processes needs to be adapted to the farmers.

6 FUTURE PERSPECTIVES OF DEVELOPMENT

The socio-technical view of Mollinga (2003) has shown the links of the context in which the design is placed. The basic elements of the system are formed by ´technology´, ´people´ and ´forms of organisation´. With the irrigation scheme in place and given its context the main focus here remains how ´technology´ is used by the ´forms of organisation and people´ to fulfil irrigation. Thereby the main objective is to derive resource flows in order to improve the livelihood of the farmers, building the social effect of irrigation as explained with the sustainable livelihood framework. The main programme objective remains to achieve food-security in the area and thus to supply farmers with supplemental irrigation. There is no doubt that the future of the irrigation system will depend on the operational targets and how these are met and managed, not only at scheme level but also at field level. To indicate how the system will serve the farmers throughout the scheme, the first section takes a look at the irrigation feasibility of full development by using the programme CROPWAT 8.0 in §6.1. In the future, performances should be improved, or sustained. In this sense, it is important to indicate possible issues to be addressed, to assure sustainable management for the future, discussed in §6.2.

6.1 Feasibility

In this section, feasibility is assessed on whether the water demands of the farmer can be met with the available water supply. With the calculation of the crop water requirements it is possible to have an indication of the irrigation requirements for the command area. CROPWAT is used to show how the soil moisture changes over time. In general farmers wait for the rains to come in the *belg* season to prepare their fields in advance of the *keremt* season and are not using pre-irrigation. An example to show the difference is given by growing maize with and without pre-irrigation starting from the 1st of June until harvest time on the 18th of October shown in Figure 6.1. Critical differences are seen in relation to the initial soil moisture. Based on the experience of farmers to have low yields or no production due to water stress, an initial soil moisture of 40% is used. In the figure the growth begins with half the field capacity or 40% initial soil moisture, here it is seen that it already suffers from water stress. The RAM is crossed by the red bars, indicating ´depletion´ and occurrence of water stress. In the project area the initial soil moisture could be low or even lower and this would make the crop suffer severely. If the initial soil moisture was at field capacity it would develop as indicated with the line FC and it would not suffer from any water stress.

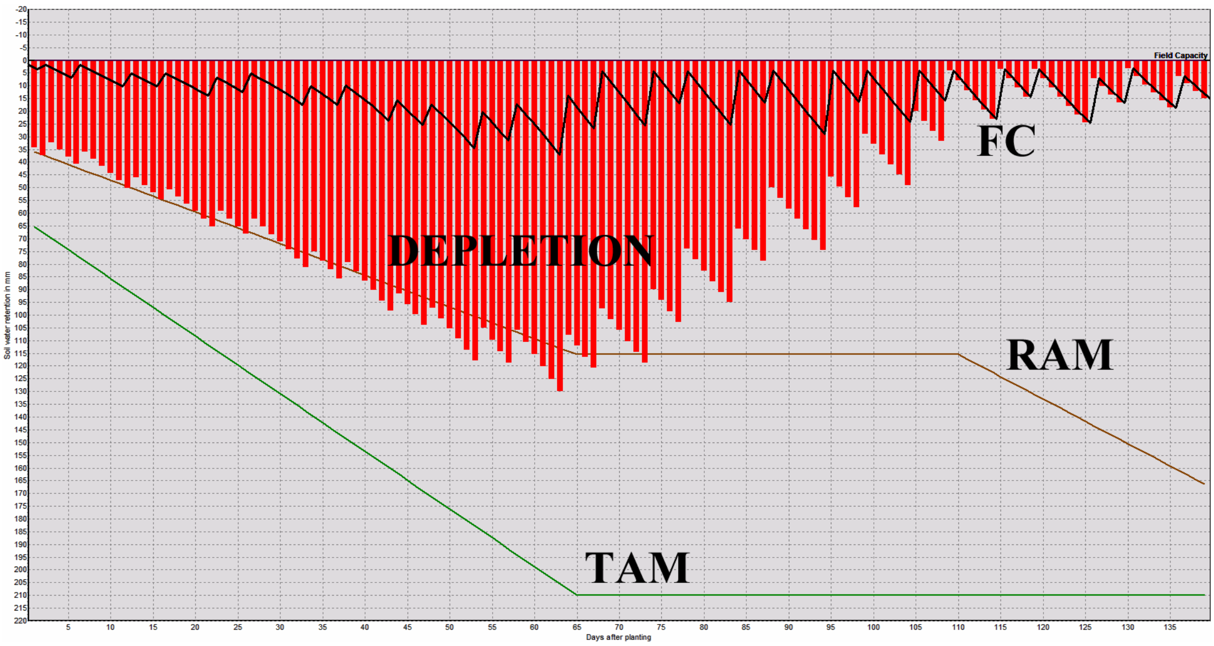


Figure 6.1: Occurrences of water stress: pre-irrigated, or rainfed maize (CROPWAT 8.0)

The spate irrigation can be used to pre-irrigate the plots up to field capacity. Hereby water stress can be overcome during the 'initial' and 'crop development' stages. Figure 6.1 shows it is possible to grow maize in the project area, without giving any additional irrigation besides pre-irrigation. Maize has a long irrigation interval. But as explained before it is the farmers who decide what crops to grow and how many hectares are used for a certain crop. For the total analyzes of the crop water requirements in the command area all crops grown should be taken into consideration. For this reason the growth of the main crops have been estimated based on secondary data and based on the experience of the agronomist. Hereby is assumed that the crops will be all planned the 1st of June, to give enough time for pre-irrigation and to make optimal use of the *keremt* season. Another important aspect as shown earlier is the initial soil moisture, for this analysis also 40%[41] initial soil moisture is used. This information together with the data of the climate[42], the crops and the soil makes it possible to calculate the crop water requirements and the irrigation requirements for the whole scheme. To see whether the water demand can be covered by the available water supply, the water supply needs to be specified more in detail. In §3.1.5 the water supply has been calculated based on the rainfall in the catchment areas. In this calculation conveyance efficiencies of the scheme were not considered. Without more specific detailed information about losses, these are based on the spatial dimension and the design and estimated;

E_{c1} = Losses of the main canal; seepage, evaporation, intake losses
E_{c2} = Losses of the secondary canals; seepage, evaporation, intake losses
E_{c3} = Losses at field level for the field application; intake losses and operational losses

As discussed in the design the first section of the main canal is lined to prevent losses, but the remaining part remains very long and is not lined. Nevertheless the 'cross-level' drain structures discussed in §4.1.2 makes it possible to compensate losses of the main canal. For this reason the losses of the main canal are not considered in this calculation. For the secondary canals the losses are taken into account for long earthen canals. Halcrow in Tesfari (2001 p.20) estimated these conveyance efficiency at 50%. Also according to the FAO clarified in APPENDIX 6, the conveyance efficiency can be estimated at 50%, which will be used for further calculations. At field level, losses occur due to deep percolation and run-off. The total conveyance losses E_{total} is calculated in equation 6.1.

$$\mathbf{E_{total} = E_{c1} * E_{c2} * E_{c3}} \qquad \text{(eq 6.1)}$$

In table Table 6.1 the losses of the secondary canals are taken into account for the water supply and the losses at field level are calculated by the gross irrigation requirements as

Table 6.1: Calculation total CWR and available water supply for single crop season

Crops	Growing days	Sowing Date	Harvest Date	Hectares (Ha)	Percentage	Net Irrigation Requirements (mm/month)				
						Jun	Jul	Aug	Sep	Oct
Maize	140	1 June	18 October	3250	65%	84	0	0	0	0
Sorghum	130	1 June	8 October	1050	21%	84	0	0	0	0
Bean	100	1 June	8 September	600	12%	84	0	0	0	0
Wheat	150	1 June	28 October	50	1%	84	0	0	0	0
Onion	150	1 June	28 October	50	1%	84	0	29,4	57,1	28,7
Total (per Ha)				5000	100%	84,0	0,0	0,3	0,6	0,3
Total gross field irrigation ($e_f = E_{c3}$ = 50%) (mm)						168,00	0,00	0,59	1,14	0,57
Total CWR demand for 5000ha (m^3/s)						3,24	0,00	0,01	0,02	0,01
Total net available supply (m^3/s) ($E_{c1} * E_{c2}$ = 1 * 0,5)						1,42	2,30	2,36	1,65	0,59
Total net remaining water availability (m^3/s)						-1,82	2,30	2,35	1,63	0,58

[41] This figure is roughly estimated using CROPWAT 8.0 by evaluating the need of pre-irrigation to avoid occurrence of water stress without irrigation, for maize this was (50%) and for sorghum (40%) in the project area.
[42] ET_0 Penman-Monteith was calculated from climatic data and effective rainfall with the USDA S.C. method.

explained in equation 5.8. In Table 6.1 the total calculated ‘net remaining water availability’ indicates that with the calculated supply the system cannot meet the irrigation requirements in June. Most irrigation is supplied for pre-irrigation, unfortunately this cannot be covered with the available water supply in June. For this reason also pre-irrigation should take place in April and May and since both months have relative high water supply, pre-irrigation can be feasible. Onion[43] clearly shows that it requires more irrigation than the other crops and based on the proper functioning of the irrigation scheme more farmers could be interested growing onion or other more water demanding crops. So far is seen from the calculation that with a single crop season, water supply is sufficient for cereals. However another possibility for increasing production has been intended by the agronomist by growing a double crop season. Also here the irrigation requirements need to fit the available water supply. But the crop seasons are of major influence on the total crop water requirements for the scheme. The first crop season as discussed earlier will be completely dependent on irrigation. Therefore this cannot start before water can be supplied. The Boru river is flowing adequately starting from February-March. For this scenario the date of sowing of maize and sorghum is the 1st of March, the sooner the better, because after October the supply of water for irrigation is very limited and decreasing.

Table 6.2: Calculation total CWR and available water supply for double crop season

Crops	Ha (%)	Harvest Date 1	Ha (%)	Harvest Date 2	Net Irrigation Requirements (mm/month)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize	50%	18 July	65%	6 Dec	0	0	40,6	104,3	119,1	0	0	0	0	0	117	0
Sorghum	50%	8 July	21%	26 Nov	0	0	41,9	129,9	148,6	0	0	0	0	0	0	0
Bean	0	-	12%	27 Oct	0	0	0	0	0	0	0	0	0	0	0	0
Wheat	0	-	1%	16 Dec	0	0	0	0	0	0	0	0	0	0	141	0
Onion	0	-	1%	16 Dec	0	0	0	0	0	0	0	0	56,5	113,4	86	27,6
Total (per Ha)					0,0	0,0	41,3	117,1	133,9	0,0	0,0	0,0	0,6	1,1	78,5	0,3
Total gross field irrigation (ef = E_{c3} = 50%) (mm)					0,0	0,0	82,5	234,2	267,7	0,0	0,0	0,0	1,1	2,3	156,9	0,6
Total CWR demand for double season (m3/s)					0,00	0,00	1,59	4,52	5,16	0,00	0,00	0,00	0,02	0,04	3,03	0,01
Total net available supply (m3/s) (Ec1 * Ec2 = 1 * 0,5)					0,29	0,53	0,98	1,03	1,12	1,42	2,30	2,36	1,65	0,59	0,19	0,06
Total net remaining water availability (m^3/s)					0,29	0,53	-0,61	-3,49	-4,05	1,42	2,30	2,36	1,63	0,54	-2,83	0,05

Table 6.2 shows directly that growing a double season will have several constraints. In the calculation the first crop season covers also 5000ha and this results in a serious lack of available irrigation water. If the command area is decreased to 1000ha a very small surplus remains. This shows that only few farmers can benefit from double cropping seasons and that water shortage can appear. The second crop is sowed at the 20th of July and uses the same cropping pattern as used before, it show that with especially the growing of maize in the second crop season a deficit can be expected. If instead of maize sorghum or beans would be grown sufficient irrigation water would be available here as well. An overview of the expected rainfall, available water supply and CWR with cropping patterns is shown in APPENDIX 7.

6.2 Sustainability

The development of the irrigation system will need to deal with many uncertainties. The objective is to improve and assure the livelihoods of the beneficiaries, hereby it is important to achieve sustainable development. ‘Sustainable development’ can be defined in various way, the ‘2002 Johannesburg World Summit on Sustainable Development’ defined it as “the management and conservation of the natural resource base, and the orientation of

[43] In CROPWAT 8.0 it is not possible to calculate below 1% in the cropping pattern. Initially 25ha of pepper was planned but instead onion has been doubled.

technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations" (Haile, 2007:8). According to Haile (2007) this would entail for spate irrigation the conservation and management of land, water plant and animal resources in a technical appropriate, economical viable and socially acceptable manner. To achieve this 'sustainable development' the technological and institutional aspects are central for achieving changes. This is similar to the approach of the livelihood framework of the DFID (1999), which takes transformation structures and processes as central for changing access and influences to assets. The institutions are responsible for the management of the technology. If the design is considered it is able to distribute the water, but the main uncertainty here is how this distribution is managed and controlled. Not only at scheme level but also at field level, the water distribution requires skills and capacities and it is questionable whether the social adaptations of the OWWCE and WUAs can be deployed and established. Also with irrigation it is unsure whether all farmers will benefit from it and whether this will be equal, or result in unequal water distribution throughout the scheme, or upstream-downstream conflicts and theft. Another important matter is the fact that the technology is also dependent on nature. According to Haile (2007:8) "The basis for developing land and water resources is to have an accurate assessment of their current availability and their potential". Unfortunately spates makes it very difficult to predict the water availability, but water resource assessments are essential for achieving proper management. The uncertainties of water availability for the Dodota scheme, coming from the hydrological data makes it doubtful whether this scheme can deliver proper irrigation. In relation to the estimated single cropping patterns irrigation supply seems feasible, but the variability in water supply hasn't been taken into account. For double crop seasons it seem impossible to cover the complete command area in both seasons, and major changes in the cropping pattern are required. Another constraint for the double crop season is the problems it causes for free grazing. The solutions for these issues are to be solved by the future management. In case of sustainable management, it is required to anticipate on these issues and to take the positive social effects on the long term into account. It must be understood that the future of the system depends on the realisation of these social effects, which is at the end the pay back to the users, who are required to keep the system in proper shape for maintenance and operation.

6.3 Conclusion

This chapter has shown how the total crop water requirement is related to the total available water supply. Even though the unpredictability of spate irrigation remains, an assessment of the water availability can indicate the extend to which irrigation is feasible. The calculation has indicated that with a single crop season, supplemental pre-irrigation is sufficient. Here pre-irrigation can be used to prepare the fields and the initial soil moisture can be improved and retained. With a double crop season it has turned out that changes in the command area and cropping patterns are required. This implicates that not all farmers can benefit equally and decisions have to be taken at scheme level and at field level. The irrigation system is designed to distribute the water but the management is responsible for the coordination and control. Sustainable development focuses besides technology mainly on the suitable management of the scheme to deal with issues and to realise positive social effects in order to sustain proper operation and maintenance.

7 DISCUSSION & CONCLUSIONS

The aim of this research was to understand the construction and design of the system, the water management and the field- and soil management of farmers in the Dodota spate irrigation system. The objective was to assist on the debate, whether new systems are as manageable, equitable, reliable and environmentally friendly as Ethiopian policy has promoted. The main research question presented in the first chapter of this report was:

"How is water management taking place in the new Dodota spate irrigation system and what are the impacts and effects for irrigation, soil conservation practices, and production?"

This question has been divided in to two parts and is answered accordingly, firstly it is clarified how water management is taking place in the Dodota irrigation scheme and secondly how irrigation, soil conservation practices and production are shaped by main water distribution. For both parts the sub questions of the first chapter are answered and discussed individually. The last section concludes with an evaluation of the objective and recommendations of this study for sustainable water management in the Dodota irrigation scheme.

7.1 Research questions

1st Part: How is water management taking place in the Dodota spate irrigation system?

- What infrastructure choices and design principles have been used in the system?
The Dodota system is the first large scale spate irrigation system in Ethiopia and is developed and constructed by the government. In a modern design several aspects important for spate irrigation have been taken into account. For the design permanent structures have been chosen to assure certain control over water and to decrease required labour for repair and maintenance of structures. This resulted in a so called 'controlled system' with permanent infrastructure to deal with irregular spate flows, natural drainage, erosion and sedimentation. The system is also considered 'conventional' because it relies on a semi-permanent flood stream and has a limited diversion capacity and smaller sizes of structures and canals. The water distribution is based on the spatial dimensions of the system, the main canal, secondary canals and tertiary units and can be arranged accordingly for proportional and or rotational distribution. The system gives the possibilities to coordinate and control the water by vertical gates with upstream control, but is not designed to differentiate between delivery of water to different command areas and or crops. This results in a system with flexible water distribution but high requirements for operation and maintenance. The latter aspects have not been taken into account properly, especially concerning the required skills and capacities for participation of the farmers.

- How is operation and maintenance established?
The system covers a command area of approximately 5000ha. Here sophisticated structures such as the head work, spillways and division boxes have been constructed together with in total 67.3 km of canals with hundreds of drop structures. For proper maintenance and operation the system requires skills and capacities and a strong organisation. But the agrarian structure is typified by the dependency on food aid and a poor development status. For this reason the government has given a mandate to the OWWCE to arrange the operational and maintenance activities of the main and the secondary canals. The establishment of the WUAs is to take care of the coordination and control of the water distribution, maintenance and operation in the tertiary units. Currently the SNP is involved in the mobilisation of the "critical mass" to prepare the fields for irrigation by establishing tertiary canals, field canals and bunds but in the future this will be arranged by the WUAs. To make proper and

successful use of the new system, adaptation in land and water rights and cultivation practices of the farmers is essential. Here the state and irrigation institutions play an important role to involve the farmers in the operation and maintenance of the system and to transform the livelihood of farmers. However, no organisation examples of operation and maintenance are visible and trials have already damaged some structure.

- How are land- and water distribution rules (rights) arranged?
The land rights are based on the constitution, federal policy and the state policies of Oromia state. In Oromia men and woman have equal rights to land and are given so called 'user rights'. Land cannot be sold or exchanged in any way, but land can be sub rented which gives also access to land for others. Overall share cropping and rentals are the most common forms of land transactions. The land rights are established for the study area but water rights are completely new. The regional states and local administrative bodies are obliged by law to implement the National Water Policy in accordance with the directives and guidelines provided by the Federal Ministry of Water Resources. One of the fundamental objectives from this is to ensure social equity and economic efficiency, system reliability and sustainability. However, the water rights and rules which are used to meet these 'fundamentals', are decided upon by the WUAs in so called 'by laws'. Since the scheme will be jointly managed the setup of the by-laws needs to be adapted too. For the Dodota system the management at field level is completely up to the WUAs who so far remain unorganised. By-laws interesting for the WUAs and farmers are mostly concerned with the application of irrigation at field level. Here it is concluded that not all rules are considered, and for the future these need to be improved to avoid future conflicts, especially concerning the depth and frequency of irrigation. At scheme level the rules related to the allocation and apportion need to be coordinated and controlled by the OWWCE, in agreement with the future WUAs. At scheme level it appears that rules are missing, especially concerning the proportion of the flow going to different branches and the sequence in which command areas are watered.

- How is water distributed over the command area throughout the irrigation season?
The OWWCE and the WUAs will be responsible for the water distribution at scheme level, which will be decided upon in the District Board of Management. The infrastructure is not differentiating according to command area or crop water requirements. This implies that coordination and control is completely up to the scheme management. Here a major issue is the availability of irrigation which is hard to predict for spate irrigation. The decision for allocation and distribution, has to be decided upon according to the directives of the National Water Policy, whereby the SNP program could be useful as shown in this study. Here the research pointed out that the command area is characterized by differences in food insecurity, indicating drought prone areas, with most severe drought prone areas in the tail end of the system. This makes the allocation and sharing rules of major importance to establish fair and efficient distribution. Additional water rights and rules with appropriate incentives and fines are needed and need to be enforced. Also the coordination and control of water distribution requires special attention and is currently overlooked. Here the functioning of the WUGL and the operation technicians from the OWWCE as additional controllers needs to be reconsidered. Better guidelines and experience is needed to achieve proper water distribution whereby fair and equitable distribution is the main objective.

2nd part: How are irrigation, soil conservation practices and production shaped by main system water distribution?

- How is water and soil moisture managed at field level?
In the study area farmers were completely dependent on rainfed agriculture and they were not experienced with irrigation in any way. Soil moisture was not considered a subject for management, but it appeared that rainfall itself played a major role for land preparation. This

practice by itself has an effect on the soil moisture; less rainfall can infiltrate and with ploughing evaporation is increased. The field management and irrigation practices are closely related. Soil conservation measures such as 'no tillage' and 'mulching' are practices which could be adapted to minimise evaporation and erosion. Pre-irrigation can be used to establish initial soil moisture at field capacity. The irrigation facilities provide new management opportunities to farmers, whereby 'pre-irrigation' and 'primary tillage' can establish sufficient initial soil moisture and support land preparation. The application of irrigation as supplemental irrigation during the growing season is dependent on the available water supply and the rainfall. The irrigation intervals and application depths for crops are an important guideline to consider. Because of the nature of spate irrigation, the water supply remains unpredictable which makes irrigation scheduling uncertain. For this reason it is preferable to focus on the initial soil moisture and grow less risky crops.

- Which crop(s) patterns are likely and preferable to be used?
In the project area, farmers were able to grow a single rainfed crop only. The crop choice is based on an individual choice of the farmers. Crops are grown to meet the families' basic food requirements and for the market. The individual choices of farmers will have a major impact for the irrigation requirements in the tertiary units, the branch canals and for the scheme as a whole and are therefore important to be considered. Hereby the main problem for spate irrigation remains similar as with erratic rainfall, it is unpredictable and not accountable. With the coming of the irrigation system there are initial plans for new cropping pattern composed mainly based on two groups of crops; full irrigation crops and supplemental irrigation crops. In the *belg* season from January to May it was unlikely to grow crops because of a high risk of insufficient rain. With the irrigation system, dry crops like maize and sorghum could depend on irrigation instead. For the *keremt* season, crops can be rainfed and supplemented with irrigation. Here more crops are selected such as; wheat, onion, pepper, haricot bean etc., and also maize and sorghum. In the feasibility study the available water supply and the crop water requirements haven been calculated. Here the water supply was based on a continuous regular flow. This study has already indicated that a double crop is only feasible, if the command area is decreased to 1000ha or less area and the crops are adjusted two less water demanding crops. For this reason it is preferable to focus on a single crop season instead, whereby it is feasible to have sufficient water available for the pre-irrigation of 5000ha. Here pre-irrigation must start in April and May and can be used to prepare the fields. As seen from last year production was significantly increased by irrigation. Most important here is to see that farmers are convinced of the beneficial effects of irrigation and are willing to contribute to the required operation and maintenance. If more risks are taken this could undermine the participation of the 'critical mass'. This study indicated some of the difficulties for double crop seasons, therefore it is advisable to experiment with double crop seasons in a later stage of development when there is more certainty about the water availability.

- Which main livelihood strategies can be distinguished?
Currently the project area is still chronically dependent on food aid and farmers have a poor developed status. The study indicated that farmers are interested in the given opportunities to improve their livelihood, starting by sufficient agricultural production to sustain their families. The sustainable livelihood framework used in this study clarified the 'social effects' of irrigation and made clear how the transforming structures and processes influencing the assets for livelihood. The government is playing a leading role to give opportunities and guidance. Hereby farmers can choose for different strategies. This study has indicated several possible strategies; adaptation of irrigation, adaptation of agronomic technology, livestock investment, agricultural business, diversification and migration. But next to these opportunities there is also a threat with the implementation of new water technology which could undermine the 'critical mass'.

7.2 Evaluation and recommendations

The objective of this study was to understand irrigation development and to see how the water management of the Dodota system was about to improve the livelihood of farmers. This study showed clearly according to the framework of Mollinga (2003), how complex and divers the relations are between the 'basic elements' of the irrigation system and the 'context'. It was difficult to study with ongoing processes and development of the scheme. However it gave opportunities to really understand the system from the 'basic elements' where 'technology' was recently designed and constructed. But the actual consequences and 'social effects' were not visible yet. Nevertheless, based on this study for the actual improvement of the livelihoods, there are many uncertainties, especially whether it will actually reaches those who needed it most. The availability of water is not sufficient to grow a double crop season and even a single crop requires efficient water distribution. This makes the allocation and sharing of essential importance. Here the management of the scheme is of main concern, since it is sophisticatedly designed and requires skilled management. Better design choices for the Dodota scheme would have been less complicated and ambitious structures which need less manpower for operation and maintenance. The cost for the maintenance and operation are in this situation not even considered, but it is pretty clear that without the support of the government the system could not be supported by the farmers. The income with a single crop remains low. This implies that even with marginal benefits several transformation structures and processes are needed and ongoing at the same time for now and in the future. Hereby it is not only the system which enables irrigation development but especially the follow up. Eventually the adaptation of water management at all levels is of major concern for farmers to actually improve their livelihood.

The socio-technical approach by Mollinga (2003) has shown how the irrigation system is related to its 'context'. The answers to sub questions have shown that the irrigation system is constructed whereby the water management and the agrarian structure need to be adapted. The need for technology is explained by 'social requirements', because due to the drought and erratic rainfall, people have been unable to produce sufficiently. The second dimension resulted in a technical design based on the 'norms of materialisation', however these norms were based on high standards with a complex design and not materialised by the farmers themselves, but by the government instead. The farmers themselves were not able to construct this scheme but they could not survive without sufficient water. For this reason the government found a sophisticated technical solution. The last dimension should close the circle and lead to technology to 'support and meet the social requirements'. But it can be striking if technology is not meeting the social norms, based on the capacities of the social environment in which it is placed. The situation in the scheme has made it economically viable to design and construct a sophisticated system. However, in practice it turned out that the technical aspects and social aspect do not match. For this reason the government is developing new organisational arrangements that link technical requirements and operational capacities (Kimani & Ubels in Pant 2000 p.15). These operational capacities however were not only dependent on the management of the government but also on the management by the farmers. But also here transformation is depending on the government, thus at the end the government is completely responsible for the management and transformation structures and processes at all levels. But there are challenges to succeed in the social changes and establishment of operational capacities needed for proper operation and maintenance. This actually showed that the Ethiopian government used a technocratic approach to deal with a social problem, but besides the development of technology also social developments are required and essential. Therefore it requires the farming community and the government to adapt to the system.

The critical aspects for irrigation are pointed out in the framework of Mollinga (2003) by the ′basic element′. This study has shown that some aspects require more attention and need to be addressed in particular for spate irrigation. These are; the water availability, the sophisticated infrastructure and the water distribution required for direct irrigation, for which operation and maintenance are essential aspects. Proper operation and maintenance is of major concern to establish contribution of the ‘critical mass’ and a viable and sustainable system.

The semi-perennial water supply made engineers develop the design of the Dodota spate irrigation system as a more conventional irrigation system. The study has shown that the infrastructure is sophisticated and can easily lead to complications. The study illustrates that the distribution in the system is difficult to coordinate and control and gives little reference to known challenges of spate systems. The operational and maintenance will require heavy machinery and skilled people. Strict management will be required to coordinate and control the distribution to achieve optimal and fair sharing.

Spate irrigation is known to have an uncertain and unpredictable water supply and also for the Dodota system the variability is only roughly estimated. To deal with these uncertainties it is advisable to limit the uncertainties and focuses on the realisation of feasible objectives with less risk. First, better insight in the actual water division and distribution is preferable and by monitoring the water availability and the crop water requirements, water management can be improved. This study has indicated that it is sustainable to use pre-irrigation for a single crop season. Hereby the issues concerning livestock are also avoided. Farmers can significantly improve their livelihood and with better monitoring, experiments of double crop season can be initiated.

Next to the ‘technology’ and ‘water’, it is the ‘forms of organisation and people’ who arrange the water distribution. Here the low development status of the farmers and the need for governmental support are apparent. The adaptation to irrigation practices at field level is mainly dependent on the transformation structures and processes of the government. It seems like there is a distinction between the management at scheme level and at field level but actually both is very reliant on the government. This implies that at field level the key to final success is to enable the structures and processes of social transformation to succeed. Farmers need to gain trust in the system, to actually invest in the system. If farmers adapt to the system, contribution is established. If farmers are given opportunities, strategies to improve their livelihood seams reasonable. For this to happen, the system needs to be accountable and thus supply the farmers with actual irrigation. The system should improve their livelihood, but if too many risks are taken it could have a counter effect. The success of the system will depend on the actual performance of the system to enable farmers to increase their production.

For the future development of the irrigation system it is important to achieve sustainable water management. Here technological and institutional aspects are central for achieving change. For this reason it is important to understand how transforming structures and process changing access and influences to assets and thus the livelihood of farmers. Sustainable management needs clear policies and guidelines to establish fair water sharing to improve the livelihood of all farmers. Here it is very important to support these structures with required education and training to establish proper operation and maintenance. The future of the system depends on the realisation of beneficial social effects, which is the pay back to the users, who are required to keep the system in proper shape for maintenance and operation.

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APPENDIX 1

Based on the available information from the Asella station, an indication is given of the possible maximum rainfall per day in the catchment area from the years 1990 up to 2004. With a high amount of rainfall in a short duration, large floods can enter through the Boru river and can cause damage to the infrastructure. To have an indication of the dependability, the formula of Wiebull 'r/(n+1)', explained by Dries and Gerbrandy (2006 p.51) is used, to come up with a maximum peak rainfall with an occurrence of 1 out of 148,9 years, approximately 150 years. The calculation is shown in Table 7.1 and the result is depicted in Figure 7.1.

Table 7.1: Calculation for the gumble of the peak rainfall

Nr	Year	Daily maximum rainfall (mm)	Ranked	F=r/(n+1)	Y= ln(- 1/ (ln F)	e^-e^-y	T= 1/(1-e^-e^-y)
1	1990	42	42	6,25%	-1,02	6,25%	1,1
2	1991	42	42	12,50%	-0,73	12,50%	1,1
3	1992	61	44	18,75%	-0,52	18,75%	1,2
4	1993	55	48	25,00%	-0,33	25,00%	1,3
5	1994	56	51	31,25%	-0,15	31,25%	1,5
6	1995	51	52	37,50%	0,02	37,50%	1,6
7	1996	48	54	43,75%	0,19	43,75%	1,8
8	1997	88	55	50,00%	0,37	50,00%	2,0
9	1998	64	56	56,25%	0,55	56,25%	2,3
10	1999	54	57	62,50%	0,76	62,50%	2,7
11	2000	52	61	68,75%	0,98	68,75%	3,2
12	2001	69	64	75,00%	1,25	75,00%	4,0
13	2002	44	69	81,25%	1,57	81,25%	5,3
14	2003	80	80	87,50%	2,01	87,50%	8,0
15	2004	57	88	93,75%	2,74	93,75%	16,0

From the measurements and the calculation it becomes clear that every two years a peak rainfall of 55mm can be suspected. It depends on the diversion capacity to make significant use of this flood for direct irrigation, otherwise the overall efficiency will be lower.

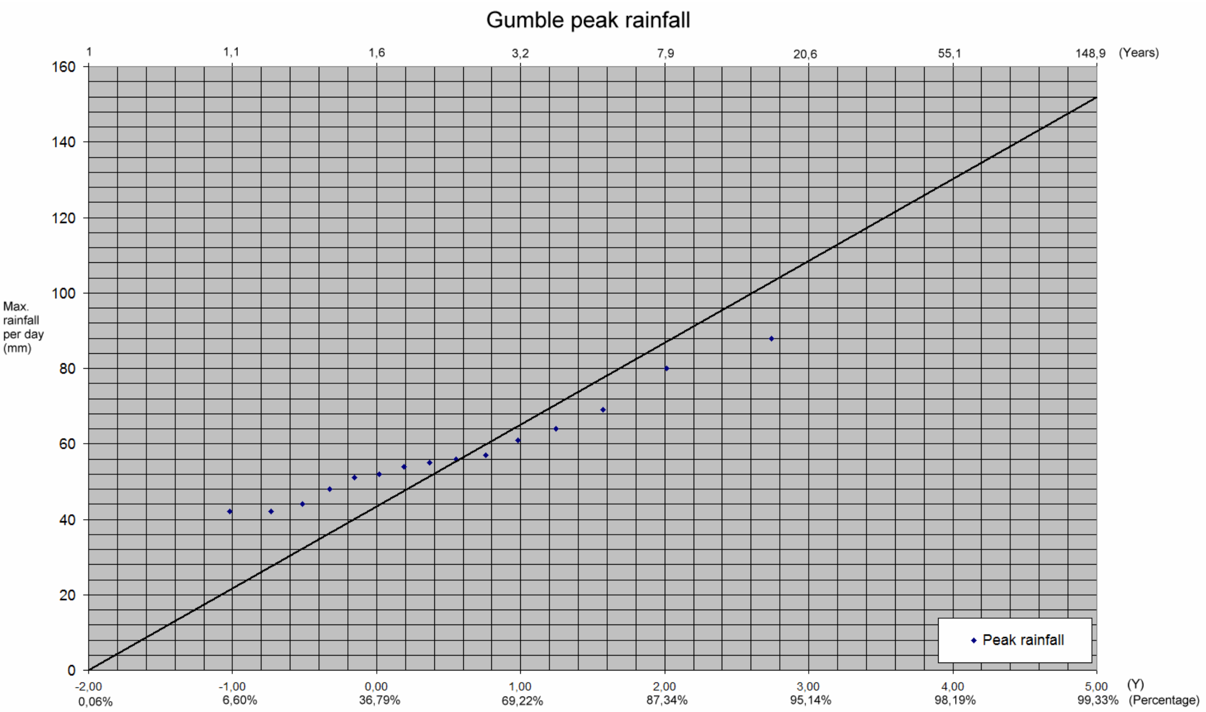

Figure 7.1: Gumble of peak rainfall showing the occurrence of maximum rainfall per day

APPENDIX 2

Here the activities and responsibilities of the OWWCE, the OWRB and the BARD are given from the operation and maintenance manual (Derese, 2008).

OWWCE, the Enterprise's duties and responsibilities in general are stipulated in its establishment amendment regulation follows:

- Construct urban, rural water and sanitation schemes
- Carrying out drill water wells and boreholes according to the client's design specification and study
- Carrying out rehabilitation and maintenance work
- Carrying out construction works
- Provide Maintenance services for its own and for other client equipment and vehicles
- Engage in construction of dam and river diversion works on contractual basis
- Produce and sell water related materials and equipments
- Construct and own large-scale irrigation and drainage schemes according to the client's design specification and study.
- Own and manage large irrigation schemes.
- Carry out operation and maintenance of irrigations systems and collect water charges in accordance with the cost recovery directives to be issued by the regional state.
- Issue, sell and pledge bonds.
- To engage in other related activities necessary for the attainment of its purpose.

OWRB is responsible for the following irrigation activities;

- Control and monitor all developed irrigation scheme going on in the region in such a way that it does not bring up effects both on the surrounding and downstream community and natural resources.
- Investigate and approve soil chemical and physical properties and irrigation water quality before using it for irrigation purposes and collect available studied documents in the country studied by different institutions for use.
- Re-commission the completed irrigation schemes to the beneficiaries, follow up and supervise the safety of the scheme in collaboration with Users Association or Cooperatives, NGOs, *woreda* and local administrative organs and make the undertaking of rehabilitation and maintenance of the same where it is found to be beyond the capacity of the beneficiaries.

BARD responsibilities include the following activities;

- Promote both rain-fed and irrigation agricultural development within the region
- Implement rural land use and land distribution policy
- Provide agricultural and rural technology with proper extension service to farmers for rain-fed and irrigation farms.
- Provide research service to farmers for rain-fed and irrigation farms.
- Provide adequate and timely agricultural inputs, farm implements and credit services to farmers.
- Ascertain that laws, policies and directives issued for the purpose of protecting the regions soil, water and other natural resources are fully adhered to.
- Provide agronomic and irrigation water management trainings and technical support to beneficiaries and other stakeholders for proper utilization and sustainability of the schemes.
- Study, implement and monitor different water harvesting technologies and provide water saving materials that are easy to handle at individuals or in a group.

- Undertake the study and design of soil and water conservation activities related to irrigation schemes.
- Avail irrigated agriculture extension services to the beneficiaries so as to make them enhance their productivity with the use of irrigation schemes.
- Cooperate with concerned bodies to control water borne disease, water pollution and others that may occur as a result of irrigation development.

APPENDIX 3

Table 7.2: Calculation of the 'total ratio' for the project area.

Branch canal	Calculated field area (ha)	Potential Irrigation area (ha)	Woredas	Kebeles	Kebele population	Local population	Sum local population	Food aid beneficiaries	Population ratio	Food aid ratio	Total ratio
1	60	258	Dodotaa	Dilfekar	4063	0	0	1753	0,00	-	0,000
1	319		Dodotaa	Lode Sharbe	2857	607	5136	778	0,12	0,15	0,018
1	653		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
1	209		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
2	3	599	Dodotaa	Amigna Debeso	5469	0	3378	1237	0,00	0,37	0,000
2	199		Dodotaa	Dilfekar	4063	0	0	1753	0,00	-	0,000
2	812		Dodotaa	Lode Sharbe	2857	1747	5136	778	0,34	0,15	0,051
2	272		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
2	125		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
3	213	128,5	Dodotaa	Amigna Debeso	5469	491	3378	1237	0,15	0,37	0,056
3	70		Dodotaa	Lode Sharbe	2857	0	5136	778	0,00	0,15	0,000
3	32		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
3	20		Lode Hixxoosaa	Malka Jebi	4076	0	0	0	0,00	0,00	0,000
4	468	568,75	Dodotaa	Amigna Debeso	5469	1934	3378	1237	0,57	0,37	0,211
4	149		Dodotaa	Lode Sharbe	2857	1351	5136	778	0,26	0,15	0,039
5	458	1057,75	Dodotaa	Amigna Debeso	5469	953	3378	1237	0,28	0,37	0,104
5	580		Dodotaa	Dilfekar	4063	782	3048	1753	0,26	0,58	0,151
5	78		Dodotaa	Doddota Alem	6197	768	3002	3321	0,26	1,11	0,289
5	671		Dodotaa	Lode Sharbe	2857	982	5136	778	0,19	0,15	0,029
6	60	1643,25	Dodotaa	Amigna Debeso	5469	0	0	1237	0,00	-	0,000
6	103		Dodotaa	Dilfekar	4063	1990	3048	1753	0,65	0,58	0,377
6	1391		Dodotaa	Dilfekar	4063	1990	3048	1753	0,65	0,58	0,377
6	437		Dodotaa	Doddota Alem	6197	1424	3002	3321	0,47	1,11	0,522
6	382		Dodotaa	Lode Sharbe	2857	449	5136	778	0,09	0,15	0,014
7	129	508,75	Dodotaa	Dilfekar	4063	276	3048	1753	0,09	0,58	0,052
7	835		Dodotaa	Doddota Alem	6197	810	3002	3321	0,27	1,11	0,300
7	44		Dodotaa	Lode Sharbe	2857	0	5136	778	0,00	0,15	0,000
7	87		Dodotaa	Tedecha Guracha	7856	287	287	3028	1,00	10,55	10,550
Total	8859	4764			26442	14851	14851	10117			

APPENDIX 4

The characteristics of the soil type have been determined by irrigation engineers Kebebew and Mengistu (2007). From several soil samples taken from the project area they determined a "silty clay loam" texture with (17.1% sand, 39.9% clay and 43.0% silt) based on the USDA soil texture-class triangle shown in Figure 7.2. Based on the soil particles of '39,9% clay' it is seen that the soil texture is very close to 'silty clay'.

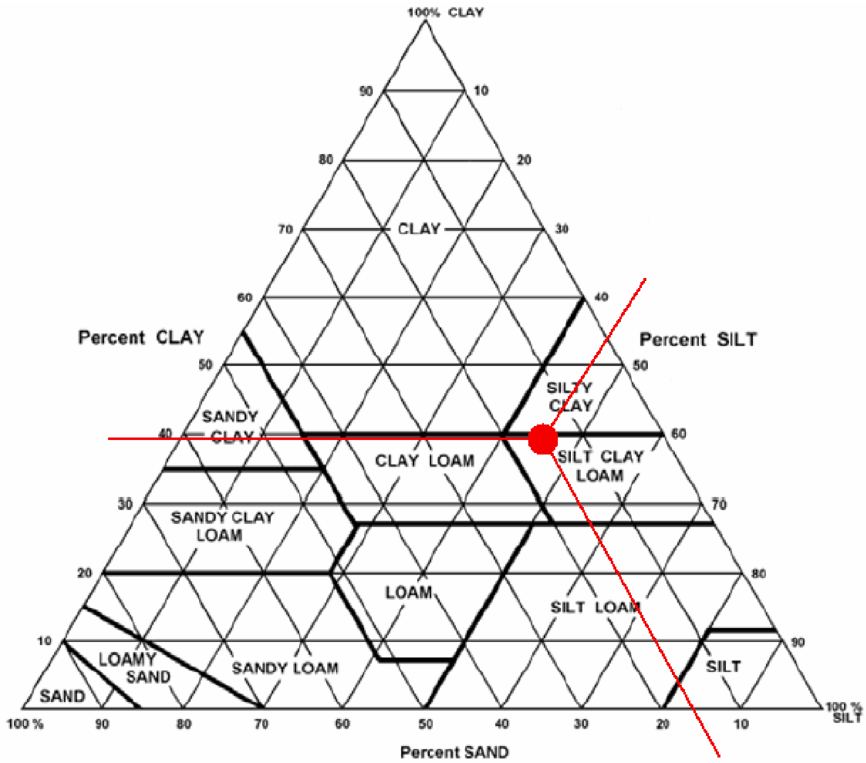

Figure 7.2: USDA soil texture-class triangle with 'silty clay loam texture' findings.

APPENDIX 5

Information on the crop water requirement of several crops is presented in Table 7.3. The information has been obtained from the agronomist and from several secondary data sources. Unfortunately some input was missing, as indicated with (-), though this cropping-data was not required for making the calculations.

Table 7.3: Information of different crops to calculate the CWR

Crops	Names	Growing period	Days of growing period				Crop coefficient			Root depth (D)	Fraction (p)	Source
		(Days)	D1	D2	D3	D4	Kc1	Kc2	Kc3	(m)		
Cereals	Maize	140	25	40	45	30	0,4	1,1	0,8	1	0,6	Agronomist
	Sorghum	130	20	35	45	30	0,4	1,05	0,7	1,0-2,0	0,55	Agronomist
	Barley	120	20	30	40	30	1,15	1,15	0,25	1-1,5	-	(Allen et al, In Vanuytrecht, 2007:40)
	Wheat	150	15	30	65	40	0,3	1,15	0,25	1-1,8	0,55	FAO
	Teff	-	-	-	-	-	1,1	1,1	0,55	0,5	-	(Vanuytrecht, 2007)
Oil and protein crops	Pease	110	35	25	30	20	0,5	1,15	0,3	1	0,4	FAO
	Bean	100	25	25	30	20	0,4	1,15	0,35	0,30-1,0	0,6	FAO
Vegetable crops	Onion	150	15	25	70	40	0,54	1,05	0,6	0,3-0,5	0,25	Agronomist
	Pepper	135	30	40	40	25	0,6	1,15	0,8	0,5-1,0	0,25	Agronomist
	Tomato	135	30	40	40	25	0,6	1,15	0,8	0,7-1,5	0,4	Agronomist

APPENDIX 6

	USDA	US(SCS)	ICID/ILRI
Conveyance Efficiency (Ec)			
Continuous supply with no substantial change in flow			0.9
Rotational supply in projects of 3 000 - 7 000 ha and rotation areas of 70 - 300 ha, with effective management			0.8
Rotational supply in large schemes (> 10 000 ha) and small schemes (< 1 000 ha) with respective problematic communication and less effective management:			
based on predetermined schedule			0.7
based on advance request			0.65
Field Canal Efficiency (Eb)			
Blocks larger than 20 ha: unlined			0.8
lined or piped			0.9
Blocks up to 20 ha: unlined			0.7
lined or piped			0.8
Distribution Efficiency (Ed = Ec.Eb)			
Average for rotational supply with management and communication adequate			0.65
sufficient			0.55
insufficient			0.40
poor			0.30
Field Application Efficiency (Ea)			
Surface methods			
light soils	0.55		
medium soils	0.70		
heavy soils	0.60		
graded border		0.60 - 0.75	0.53
basin and level border		0.60 - 0.80	0.58
contour ditch		0.50 - 0.55	
furrow		0.55 - 0.70	0.57
corrugation		0.50 - 0.70	
Subsurface		up to 0.80	
Sprinkler, hot dry climate		0.60	
moderate climate		0.70	0.67
humid and cool		0.80	
Rice			0.32

Figure 7.3: Indications of the water distribution and conveyance efficiencies (FAO)

Figure 7.3 shows the indications and factors affecting the conveyance efficiencies (FAO, 1977). The ‘conveyance efficiency’ for the Dodota scheme can be estimated around 0.7, since for spate irrigation it is likely to have problematic communication and less effective management. Furthermore the ‘field canal efficiency’ can be estimated around 0.8 for ‘blocks larger than 20’ ha and ‘unlined’. Together this brings the distribution efficiency for the Dodota spate irrigation scheme at 0,56. If the ‘distribution efficiency’ is considered by itself, the FAO shows the affect of the management and communication. The difference between ‘adequate’ and ‘poor’ indicates the range and shows that an distribution efficiency of 0,5 is more likely to be expected.

APPENDIX 7

To have a better understanding of the calculations in chapter 6, the rainfall is shown again in Figure 7.4. Also the CWR of the different crop seasons and the net available water supply are shown all together in **Figure 7.5**. Finally the cropping pattern of the single crop and the double crop season is given in **Table 7.4**.

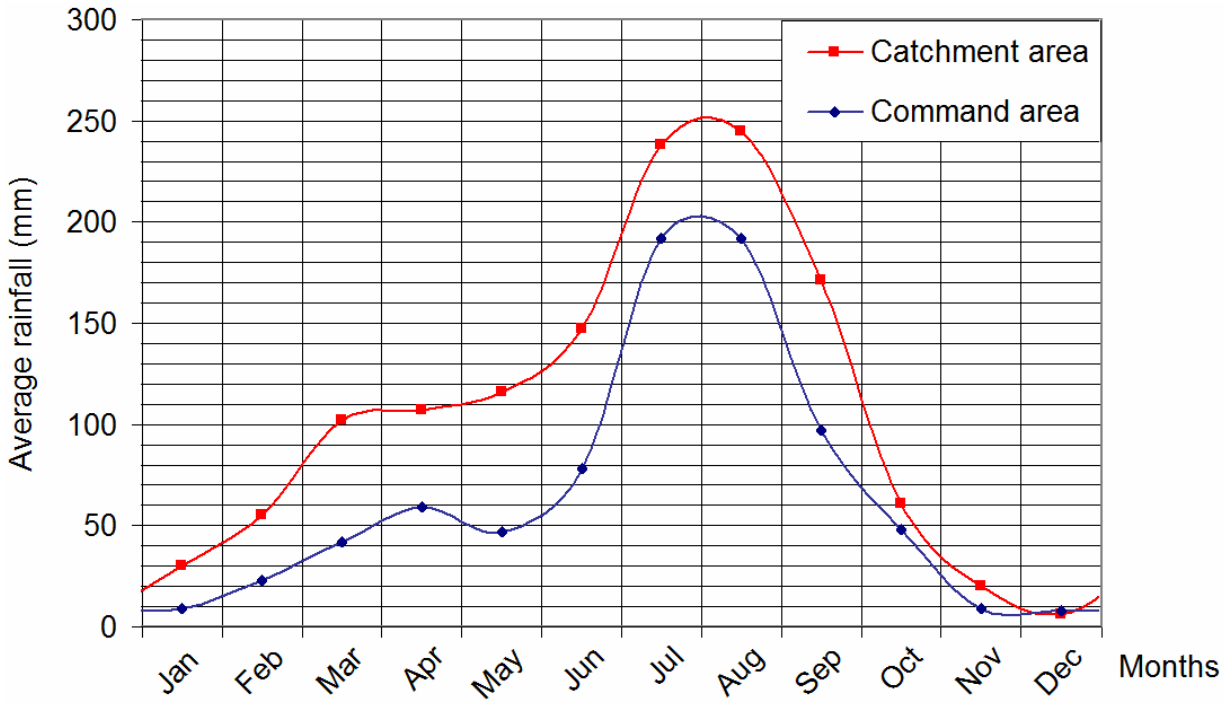

Figure 7.4: Average rainfall distribution in the catchment- and the command area (2006)

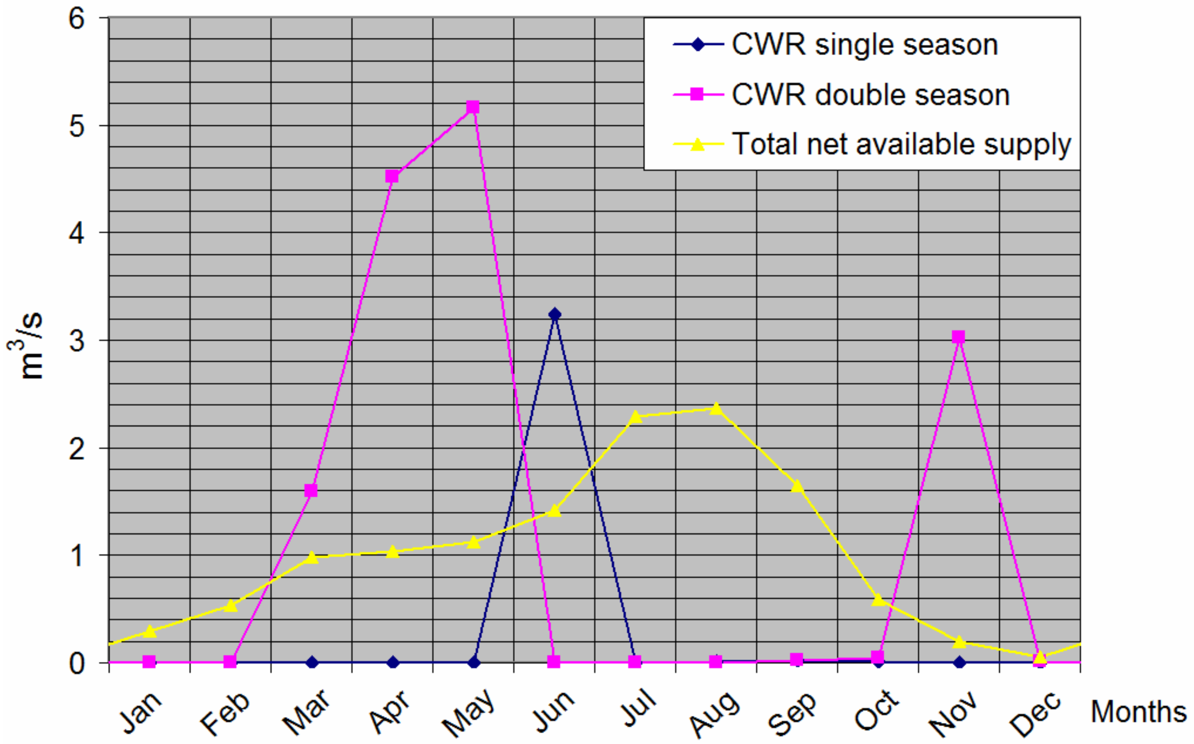

Figure 7.5: Total CWR for both cropping patterns and the available water supply

Table 7.4: Cropping pattern and cropping calendar