MSc Thesis

Presented for obtaining the Agris Mundus Master of Science
Option : Water Management for Rural Development
Specialisation : Irrigation and Water Management; Resources, Agrarian Systems and Development (RESAD)

Methodology for the Evaluation of Performances of Irrigation Systems from Farmers' Perspective. Study cases in the Irrigation Systems of Betmera and Gumselassa, Region of Tigray, Ethiopia

by Javier RODRÍGUEZ ROS

Year of defense : 2013

Host organization : CIRAD – UMR Gestion de l'eau, acteurs et usages

Photo 1: Meeting point of the WUA of Gumselassa, where water is allocated to farmers. The right green area corresponds to the Irrigation Scheme of Gumselassa during the irrigation season. Behind the hill is located the dam of Gumselassa.
Source: Javier Rodríguez Ros

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Thesis written under supervision of : Olivier Philippon

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Photo 2: Night storage of *Shanfa Geladis*. The storage is located at the upstream part of the Irrigation Scheme of Betmera.
Source: Javier Rodríguez Ros

SUMMARY

Evaluations of performances of irrigation systems in developing countries have been traditionally performed by technical experts, based on agronomic, engineering and other technical aspects. Given the little attention paid to the social dimension of irrigation, experts failed to meet the real causes behind low performances of irrigation schemes, being therefore unable to implement adequate solutions. In order to identify and tackle the base problems of irrigation systems, farmers are placed at the center of the evaluation, taking into account their key role of irrigation systems as clients and producers. Thus, this study aims to gain scientific insight into the evaluation of performances of irrigation systems from farmers' perspective, reflecting on a new methodological approach that can be useful to effectively identify the main problems faced by farmers and the solutions implemented by them. The methodology developed has been tested in the irrigation schemes of Gumselassa and Betmera, in the Tigray Region, Ethiopia, analyzing farmers' perception over the social, economic and technical dimensions of irrigated agriculture. More specifically, farmers participated in the development and implementation of an opinion poll based on a grid of 21 indicators, as well as in the analysis of the results through two WUA meetings. This allowed for further characterization of the innovations identified, one of the main objectives of the Project EAU4Food.

KEY WORDS: *Evaluation of performances; irrigation system; farmers' perception; opinion poll; indicators.*

RESUME

Les évaluations des performances des systèmes d'irrigation dans les pays en développement ont été traditionnellement effectuées par des experts techniques, sur la base agronomique, d'ingénierie et d'autres aspects techniques. Étant donné le peu d'attention fait à la dimension sociale de l'irrigation, les experts n'ont pas réussi à répondre aux véritables causes de faibles performances des systèmes irrigués, étant donc très difficile de mettre en œuvre des solutions adéquates. Afin d'identifier et d'aborder les problèmes de base des systèmes irrigués, les agriculteurs sont placés au centre de l'évaluation, en prenant compte de leur rôle clé dans systèmes d'irrigation en tant que clients et producteurs. Ainsi, cette étude vise à mieux comprendre l'évaluation des performances des systèmes d'irrigation du point de vue des agriculteurs, en réfléchissant sur une nouvelle approche méthodologique qui peut être utile pour identifier efficacement les principaux problèmes rencontrés par les agriculteurs et les solutions mises en œuvre par eux-mêmes. La méthodologie développée a été testée dans les périmètres irrigués de Gumselassa et Betmera , dans la région du Tigré , en Ethiopie , en analysant la perception des agriculteurs sur les dimensions sociales, économiques et techniques de l'agriculture irriguée . Plus précisément, les agriculteurs ont participé à l'élaboration et à la mise en œuvre d'un sondage d'opinion sur la base d'une grille de 21 indicateurs, ainsi que dans l'analyse des résultats à travers deux réunions des deux Associations d'Usagers d'EAU. Cela a permis de mieux caractériser les innovations identifiées, l'un des principaux objectifs du Projet EAU4Food.

MOTS CLES: *Évaluation des performances; système irrigué; perception des agriculteurs; sondage d'opinion; indicateurs.*

RESUMEN

Las evaluaciones de rendimiento de sistemas de riego en países en vías de desarrollo se han realizado tradicionalmente por expertos técnicos, en base a criterios agronómicos, de ingeniería y otros aspectos técnicos. Dada la poca atención prestada a la dimensión social del riego, los expertos no han logrado satisfacer las verdaderas causas del bajo rendimiento de muchos sistemas de riego, siendo por tanto incapaz de aplicar soluciones adecuadas. Con el fin de identificar y abordar los problemas de base de los sistemas de riego, los agricultores son puestos en el centro de la evaluación, teniendo en cuenta su papel fundamental en los sistemas de riego como clientes y productores. Así, este estudio tiene como objetivo obtener una mayor comprensión sobre la evaluación de rendimientos de los sistemas de riego desde la perspectiva de los agricultores, reflejado a través de un nuevo enfoque metodológico que puede ser útil para identificar eficazmente los principales problemas que enfrentan los agricultores y las soluciones implementadas por ellos. La metodología desarrollada ha sido aplicada en los sistemas de riego de Gumselassa y Betmera , en la región de Tigray, Etiopía, analizando la percepción de los agricultores sobre las dimensiones sociales , económicas y técnicas de la agricultura de regadío . Más específicamente, los agricultores participaron en la elaboración y aplicación de una encuesta de opinión en base a una red de 21 indicadores, así como en el análisis de los resultados a través de dos reuniones de las dos Communidades de Regantes. Esto permitió la caracterización de las innovaciones identificadas, uno de los principales objetivos del Proyecto EAU4Food.

PALABRAS CLAVE: *Evaluación de rendimientos; sistemas de riego; percepción de los agricultores; sondeo de opinión; indicadores.*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zones
ATA	Agricultural Transformation Agency
BoARD	Bureau of Agriculture and Rural Development
BoWRME	Bureau of Water Resources, Mines and Energy
CoSAERT	Commission for Sustainable Agriculture and Environmental Rehabilitation in Tigray
CoP	Community of Practice
CWR	Crop Water Requirements
DA	Development Agent (extension worker)
DAP	Di-Ammonium Phosphate
FTC	Farmers' Training Centre
GDP	Gross Domestic Product
GNI	Gross National Income
GTP	Growth and Transformation Plan
IS	Irrigation System
IWMI	International Water Management Institute
LPA	Learning Practice Alliance
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MoWRME	Ministry of Water Resources, Mines and Energy
PSNP	Public Safety Net Program
REST	Relief Society of Tigray
SSA	Sub-Saharan Africa
WOoARD	Woreda Office of Agriculture and Rural Development

WOoWRME	Woreda Office of Water Resources, Mines and Energy
WQS	Water Quality Service
WUA	Water Users Association
WUC	Water Users Committee

Local Words

Abo-mai	Water manager
Bega	Dry season (October – January)
Belg	Dry season, moderate rains (February – May)
Birr	Ethiopian currency
Got	Small village
Ketena/kabele	Neighborhood
Kiremt	Long heavy rains (June – September)
Kushet	Large village within a sub-district
Meher	Rainy season (June – September)
Tabia	Sub-district
Woreda	District

Ha	Hectare
Km	Kilometer
Mm	Milimeter
m.a.s.l	Meters Above Sea Level
Mha	Million hectares
Yrs	Years

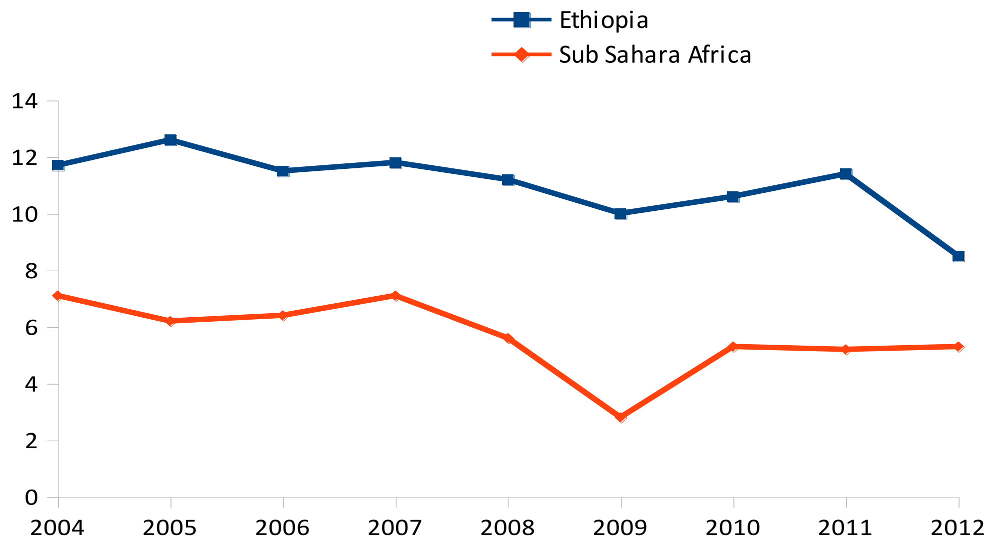
CHAPTER I. INTRODUCTION

1.1. GENERAL INTRODUCTION

Despite the fast economic growth experienced along the last two decades by many Sub-Saharan African (SSA) countries, almost half of its population currently remains under the poverty line (World Bank, 2012). During this time, poverty reduction has been positively linked to economic growth in many of these countries. The agricultural sector plays a key role to reducing poverty, given its undeniable central role in SSA countries' economies. Around 80% of SSA population lives in rural areas, being 70% of it "dependent on food production through farming or livestock" (PELUM, 2005). Thus, it is assumed that small-scale agriculture is an activity of essential importance in African economic but also in social development, being the largest sector that contributes to the GNI of these countries and employing almost two thirds of its population.

Among SSA countries, Ethiopia went through the highest growth in terms of average annual GDP (4.5%) between the years 1995 and 2010. In order to continue this trend, it was created the Growth and Transformation Plan (GTP), a five year Plan released by the Ethiopian Government. Its main goal is to improve Ethiopia's economy by achieving a GDP growth of 11-15% per year from 2010 to 2015. In the Annual Progress Report of 2011/12 Ethiopian GDP grew by 8.5 percent. Agriculture increased 4.9%, whereas Industry and Services grew by 13.6% and 11.1% respectively. Hence, Agriculture was the sector that experienced the smallest growth, being under the objective planned: 8.1% annual agricultural growth over the five-year period.

Fig.1. Real GDP growth rate rate in Sub-Saharan countries and Ethiopia between the years 2004 and 2012



Source: IMF SSA Report and MoFED, SSA excludes South Sudan

In order to meet these goals - food security, poverty reduction, and human and economic development - the Government of Ethiopia created the Agriculture Transformation Agency (ATA), which develops programs designed to support national transformation of the agricultural sector and particularly the GTP project. It is foreseen by the Government that agriculture will "continue to be the major source of economic growth" (GTP, 2012), growing at a rate of 8.6% per annum. One of the main targets addressed by this plan which last goal is to boost a steady growth is the encouragement of large-scale foreign investment opportunities in the agricultural and industrial sectors. However, the agricultural objectives planned are embedded in a strategic framework that aims to hike up productivity and production of smallholder farmers and pastoralists. Thus, the Ethiopian MoFED establishes in 2011 that small-scale irrigation is a policy priority for tackling rural poverty and enhancing economic growth, as well as climate adaptation (GoE, 2007). Other measures targeting the same objectives concern reinforcing marketing systems, fostering and improving private sector's participation and expanding the amount of land under irrigation. Indeed, the role of irrigated agriculture to meet African country's needs to increase their productivity and feed their population has proven to be crucial, contributing to largely decrease the number of chronically food insecure households.

Enhancing food security in Ethiopia is intended to be achieved through the improvement of the access to higher yielding varieties of seeds and fertilizers, ameliorating soil fertility, reinforcing technical training and promoting access to credit. One of its main limitations typically was the "lack of modern inputs for the subsistence sector" (Alemayehu, 2006), including pesticides and specifically fertilizers, which today play a major role in Ethiopia's irrigation water management in terms of water rights and allocation. Other typical constraints to overcome in order to attain the expected results concern inadequate availability of credit and poor credit recovery. All these features have been identified as factors that prevent the agricultural sector from achieving its social, economic and technic potential. In order to cope with these constraints the support of Development Agents (DAs) was implemented at local level (Tabia), as well as Farmer Training Centers (FTCs) at Woreda level and Societies such as REST at a Regional level.

In order to overcome these limitations, a large number of irrigation projects have been implemented with the objective of improving the productivity and allowing a stable production throughout the whole year, ensuring food security. Specifically in dry-land areas of developing countries, such as the region of Tigray, irrigation interventions have recorded yield increases by 100% to 400% (FAO, 1997). Only one third of Ethiopian cultivable land – Around 15 million hectares - is currently cultivated, 640,000 ha out of them under the form of irrigation schemes (Awulachew, 2010). Ethiopia's water distribution supplies to the mentioned irrigated land 93% of its water resources, leaving 6% to the domestic sector and 1% to the industrial one (Eyasu, 2005). And even though the number of hectares increased over the last 15 years – 190,000 ha in 1997 -, current trends point out the end of irrigation expansion. Irrigation can indeed assure crop production and allow multiple cropping, but it requires proper management to meet the objectives set. Through poor management of irrigation systems crop yields have been considerably reduced and land even abandoned, caused by environmental constraints such as waterlogging, salinity, erosion and sedimentation of reservoirs (Umali, 1993; Ritzema, et al, 1996; Eyasu, 2005). It can be therefore stated that the sustainability of irrigation schemes plays a key role in reducing poverty and ensuring food security in dry areas.

The two study sites selected for this research, Gumselassa and Betmera, suffer from the mentioned environmental hazards, preventing farmers from achieving the levels of productivity and production targeted. The first scheme, Gumselassa, is an irrigation system of less than 20 years of performance, which consists of an earthen dam from which water is supplied to farmers during the dry season. The lack of drainage and improper management has led to severe salinization linked to waterlogging. On the other hand the dam is experiencing progressive siltation, due to a deficient planning, which is reducing the capacity of the dam itself. The second irrigation scheme, Betmera, is a traditional system where farmers, during the dry season, divert water from the main stream and collect it at the night-storages to irrigate. However, the proximity of farmers' plots to the stream has caused serious problems of erosion, reducing the total irrigable size, removing valuable topsoil and provoking the loss of nutrients and organic matter.

This research contributes to the characterization of such kind of problems faced at both study sites, focusing on the perceptions of the users towards irrigated agriculture. Nevertheless, this is done not by specific or comparative analysis, but through the development of a methodology that sets the basis for a generic evaluation of irrigation performances. For this purpose, farmers need to be active part of the evaluation, playing a central role in the identification of the problems, its assessment and proposition of solutions that can be implemented to get over inefficient performances. Traditionally alienated from evaluation of performances (Gosh, 2005; Gowing, 1996), farmers are now placed at the center of the discussion. Being key stakeholders of irrigation water management processes as producer and client, farmers appear to be essential actors in IS's management and conception of innovations. The importance of considering irrigation as a service provided to farmers means a new approach in the evaluation of irrigated agriculture performance, changing the perspective from old approaches focused on the analysis quantitative data collection to assess the system, to a participatory approach that includes farmers as a central actor of IS.

1.2. PROBLEM STATEMENT

The Region of Tigray, located in the northern part of Ethiopia, has been scenario of recurrent conflicts along the last thirty years, contributing to its political and economic instability. In addition, some of the most severe droughts that the world experienced along the last century occurred as well in Tigray, one of the most drought prone areas of the country. However, since the last drought that happened between the years 1984 and 1986, numerous irrigation projects were started aiming to ensure national food security by increasing the yield and cropping intensity. Through the storage of rainwater during the dry season, agricultural production could be stabilized and increased, specifically in case of droughts, allowing the production of more than one crop per year (Awulachew et al, 1998). Given the constraints of irrigated agriculture mentioned in the previous section, the monitoring of the performance of the projects constructed appeared to be as important as the construction itself, presenting the network new challenges in terms of water and agricultural management for the actors involved in irrigation systems.

During a certain period of time, national states were fostering the development of new infrastructures and promoting the expansion of irrigation schemes, supported by international donors and World Bank recommendations for agricultural development. However, many states passed through difficulties in terms of financial and human resources (Jamin et al, 2011) reason why they couldn't diffuse new irrigation techniques. Furthermore, states also faced troubles when developing policies to control input and output prices and experiencing "insecurity of land tenure" (Alemayehu, 2006). These facts lead many countries to disengage from irrigation systems, bringing up a broad diversification from a social and management perspective. Moreover, it boosted farmers' adoption of individual innovations in irrigation management, freeing the situation to allow farmers' adaptations to the specific circumstances of each scheme.

As a consequence of this, researchers started to realize the scientific need to develop new methods useful to evaluate effectively these 'new' irrigation schemes. Indeed, evaluation methods used by state agencies to assess irrigation system's performance became old-fashioned and regularly lack enough knowledge about farmers' practices (Barbier et al, 2011; Jamin et al, 2011). Moreover, disciplinary approaches developed so far don't allow identifying the key determinants of evaluation, neither answering stakeholders' expectations. As stated before, among the diverse stakeholders with interests in irrigation, farmers have been very often screened out from the evaluation of the performance, being partly because of the problems faced when aiming to get "reliable measurements of performance at farm level" (Gowing et al, 1996). This could have counterproductive effects when attaining the objectives of increasing agricultural production, given the central role of farmers in irrigated agriculture. It seems therefore necessary to face the question of how to undertake an effective evaluation to analyze these systems' performances by achieving a sufficient understanding of the agricultural systems and practices.

According to Le Grusse et al (2009), new approaches for assessing 'new' irrigation systems with multi-criteria performances call for new indicators. This research designs a grid of set indicators used by other researchers and analyzes the convenience and relevancy of the results obtained, in order to reaffirm their validity or propose new indicators useful to assess generically irrigation systems' performance. However, fieldwork application of the method conceived requires specific adaptation to the context, which allows further analysis of which elements could be applicable in other scenarios and which cannot. Hence, it is believed that through the inclusion of new perspectives such as farmers' point of view, it will be possible to identify new adaptations and innovations, meant to be the "engine of social and economic development in Africa" (Wilke, 2010). These innovations aim to adapt to irrigation realities, being therefore context specific. Different irrigation schemes have diverse social, economic and environmental features, which determine different adaptations from farmers' side in terms of new social arrangements between water users and in terms of technical innovations.

For the selected study sites, different problems have been identified by farmers and researchers. These were particularly extensive for the irrigation scheme of Gumselassa, where Mekele University has been undertaking participatory research together with farmers in the areas of irrigation scheduling, crop diseases, nutrients' balance in the soil and salinity. All these problems, particularly the accumulation of soluble salts in the root zone due to improper irrigation water management and drainage facilities, caused the abandonment of many hectares of land, given its reduced value for agricultural production (Eyasu, 2005). On the other hand, at the traditional irrigation scheme of Betmera, one of the oldest irrigation schemes of the region of Tigray, researchers and farmers together claimed for soil and water conservation measures that help to increase water availability for irrigation (Solomon & Kitamura, 2006), being this the main problem pointed out at the scheme.

To conclude, the identification and analysis of the mentioned problems of both study sites targeted by this research contribute to build the basis from which the evaluation of performances will be developed. These issues are therefore taken into account and discussed with farmers in order to achieve a context-specific and precise methodology of assessment and further development of innovations. Finally, the proposed outputs – generic methodology derived from fieldwork experience, innovations and socio-technical recommendations – are evaluated and analyzed to determine its efficiency and applicability in other irrigation schemes, contributing thus to the potential scaling-up of agricultural knowledge in different contexts.

1.3. Objectives

This research aims to gain scientific insight into the evaluation of irrigation systems from farmers' perspective, reflecting on a new methodological approach that can be useful to effectively assess performances of irrigation schemes. This is embedded in a larger global goal, to contribute to increase agricultural production and improve irrigation performance through the identification and characterization of innovations analyzed in the Irrigation System (IS) studied.

To attain this objective, this research will address the following questions along the study, which will be further detailed in the logical framework in the main and specific objectives of this research:

- Realization of a critical analysis of current scientific literature, from which reflection new paths of diagnostic and alternative and integrative innovation approaches can be identified.

- To develop a new methodological approach that can be used to evaluate farmer's perspective over irrigated agricultural systems.

- Development of a survey that allows scrutinizing agricultural management practices, water supply constraints, labor implications, economic and the nature of social-institutional arrangements.

- To develop a generic grid of indicators adapted to evaluate IS from farmers' perspective, covering the social, technical and economic dimensions of irrigated agriculture.

- To identify and analyze the main concerns, objectives and needs perceived by farmers, concerning water distribution, irrigation and agronomic management at the farm level, physic and socioeconomic constraints, making them explicit.

- To specify the main problems and solutions that farmers identified regarding the grid of indicators proposed, specifying the adaptations undertaken by them in order to cope with these issues.

- To analyze the links between farmers and other actors involved in irrigation management activities, contrasting different stakeholders' evaluation of performance and enriching the links that contribute to build farmers' perception.

- To identify and characterize – define limitations and opportunities – the principal technical innovations implemented by farmers to face their problems and that could be supported and evaluated on the Gumselassa scheme in the frame of the project EAU4FOOD.

1.4. RESEARCH OBJECT

This research is framed within the Project EAU4Food, a cooperative research between the European Union and African Union to deal with the current problems of African agriculture. This Project involves diverse research centers (Alterra, CIRAD, CSIC, MU and ODI), stakeholders committed to build and scale-up knowledge with the goal of stimulating agricultural development. Partners of the EAU4Food Project focus particularly on irrigated agriculture given the key role that it has on the increase of agricultural productivity. However, this encouragement of irrigation projects has led to a higher pressure on freshwater and soil resources, which represents a new challenge in order to achieve sustainable management of irrigated agriculture's resources. Thus, coherently with the object of the Project, this research aims to develop new approaches that contribute to increase food production in Ethiopian and by extension in African irrigated areas, enhancing food security and promoting environmental sustainable practices. By doing so, this study aims to foster too new debate on key agricultural issues such as the evaluation of irrigation systems' performance from farmers' perspective.

Because of the key importance of farmers for achieving high productivities in irrigated agriculture, the object of this research is therefore to create a generic methodology that can be effectively used to gather useful information about the problems and solutions identified by farmers in different IS, testing the method through fieldwork in two IS of the Region of Tigray, Ethiopia. As a consequence of this, specific information about innovations in the schemes will be analyzed, with the aim of building knowledge on the solutions implemented by farmers to cope with the problems faced. In this context, it is researchers' task to analyze emergent innovations coming up from new challenges of irrigated agriculture, pointing out the risks and potential that they offer and more importantly detailing its social, economic and environmental viability (Jamin et al, 2011). All in all, this study aims to develop a new methodology for the evaluation of performances of IS that can be successfully applied to shape farmers' perception about it, with the objective of being useful to farmers, decision makers, land and water resource experts and policy makers.

1.4.1. SCIENCE PERCEPTION

Through the development of a methodology that sets certain indicators to evaluate irrigation systems from farmers' perspective, it will be possible to analyze accurately the specific problems that users face in their farming activities. Furthermore, it will allow identifying and characterizing the solutions that they applied to cope with their problems, with the objective of looking for innovations that potentially may be scaled-up to the whole basin and/or region. This research also aims to undertake practically the evaluation for two irrigation schemes of the Region of Tigray, Ethiopia. Thus, this will be a realist empirical case study research. A holistic and constructivist approach will be followed to evaluate irrigation systems' performance from farmers' perspective, based on an empirical analysis of its indicators studied from a social perspective. Such research entails the collection and analysis of quantitative and qualitative data, as well as the definition of possible actions that might tackle the problems studied in the research. Thus, the final goals of the research can be defined in two main concepts. Firstly, contribute to the modification on the approach of evaluation of irrigation systems. Secondly, improve the evaluation of irrigation performance by deepening into farmers' perception of it and building knowledge that can be used by all stakeholders involved in irrigated agriculture.

1.4.2. NATURE OF THE RESEARCH TOPIC

The development of this research will be done from an interdisciplinary perspective. The evaluation of irrigation systems requires an integrated approach of hydrology, agronomy, soil science, social and economic science and irrigation management. Given the complexity of a research on irrigation performance, it seems crucial to integrate all the former disciplines to achieve a successful outcome. It will be thereby based on a multi-perspective approach, social and technical, integrating the different stakes of the main actors involved and their interactions in agricultural production of the irrigation schemes of Gumselassa and Betmera.

1.5. OVERVIEW OF THE STUDY

The present study starts with a general overview of the situation of African and Ethiopian irrigated agriculture, discussing more specifically the relevant aspects concerning the region of Tigray. In this context, the current situation of the selected irrigation systems of the research is presented, identifying and describing the main problems of the schemes and objectives of the study. Then, the object of the research is presented, explaining the science perception and nature of the research topic.

Next chapter, 'Literature review', constitutes the necessary information to understand the different aspects discussed in the research, including background information of the country, region and both study sites. Besides, it is performed an analysis of Methodological Approaches in the Evaluation of Performances of Irrigation Systems, detailing the current situation of the evaluation of irrigation systems and reflecting on the evaluation principles and implications of different actors' perceptions in the assessment. Once all the theoretical concepts of the research have been set, the logical framework and main research question are presented in the next chapter, followed by the chapter 'Description of study areas and methodology'. Based on the logical framework, the methodology of the research is explained, linking the specific actions of the study that have been designed in order to attain the proposed outputs and sub-objectives set. Within the materials and methods of this research is developed the Conception of a Method for the Evaluation of Irrigation Performances from Farmers' Perspective, what responds to the need for new methodological approaches in the evaluation of irrigation systems, one of the problems discussed in the study. Next chapter presents the results obtained through the use of the methodology indicated in the preceding chapter, detailing the statistical analysis and interpretation of the results, based on observations, surveys and meetings. Finally, the Discussion serves as a reflection on the methodological considerations, quality of collected data and synthesis of the diagnostic, discussing what were the successes and pitfalls of the study and determining what elements should be taken into account to achieve an effective assessment of performance of irrigation systems. The last section of this last chapter includes the main recommendations that can be extracted from writer's perception based on the results and analyzing the opportunities that could be drafted from the study.

CHAPTER II. LITERATURE REVIEW ON EVALUATION OF PERFORMANCES OF IRRIGATION SYSTEMS

2.1. EVALUATION PRINCIPLES

In this research is developed an evaluation of performance of two irrigation systems from farmers' perspective. Hence, it is necessary to define accurately what it means and what it implies in order to set up adequately the basis of the study. With this aim, this chapter analyses the meaning of evaluation, performance and perception before further developing other aspects of the methodology of the research.

To evaluate can be defined as to follow-up, understand and pass judgment on a given situation (Chaponnière et al, 2012). Since one of the pitfalls of an evaluation system can be a biased viewpoint of it, it is important to consider plurality of evaluation, achieved by involving all the actors in a participatory or a collaborative process. However, this plurality of evaluation will be used to contrast and characterize farmers' evaluation of the system, aiming to identify and describe the main differences on the evaluation and the perceptions that cause these differences.

2.2. PERFORMANCE

The performance of a system can be defined as its efficiency, understood as the relation between actual results versus the expected results of the system (inputs and outputs). In the case of this study, the expected result of the system would be the improvement of food security and of life conditions of farmers through irrigated agriculture. The purpose of performance assessments is to achieve an efficient and effective use of resources by providing relevant feedback to the scheme management at all levels. According to Svendsen, M. & Small, L.E. (1990), there exist three categories of performance measures: process measures, output measures and impact measures. The first category refers to the system's internal operations, such as policies, organizational and communicative processes. The second one, output measures, is used to evaluate irrigation services delivered to farmers, of essential importance given its impact on agricultural production and therefore on farmers' revenue (system's final output). Last category brings up the evaluation of the effects of system's outputs in a larger scale, in the social, economic and environmental dimensions.

This research aims to analyze the interaction of the irrigated and agricultural system, which are directly linked to farmers' interest. The focus is therefore put on both process and output measures, with the objective of achieving a deep comprehension of the evaluation of performance done by farmers at different dimensions of water management. Out from these two categories, several indicators are used to assess the performance of the irrigation system, being complemented by indicators of social, agronomic and economic nature, aiming to assess accurately the "interface between the irrigation system and the agricultural enterprise" (Svendson & Small, 1990). Indeed, an exact definition of this 'interface' seems to be of remarkable importance when evaluating the performance of a certain irrigation system. The link between irrigation and agricultural practices becomes evident in practice when analyzing the influence of waterlogging and drainage systems in salinity, as well as considering water availability for the choice of crops that will be planted. It is therefore assumed that the choice of indicators to assess the system needs to cover the mentioned interface, using the most suitable indicators adapted to the context. Hence, output measures, defined by Svendson & Small as the "most relevant to understanding the relationship between farmers and the irrigation system", appear to be crucial for specifying the boundaries of the agrarian system and irrigation services, and carry out therefore the assessment. Output performance measures are here related to the groups of indicators Water Quality Service and Source of Water, which indicators will be developed in the methodology purposed in this research. On the other hand, process measures deal in the evaluation proposed with the group of Group Dynamics. Although they can mean indicators of inferior interest from farmers' perception, they play a major role in performances of irrigation systems' management and should be analyzed in order to get a complete depiction of it. Thus, this study sets the basis of the evaluation on output and process measures of performance, defining a precise scenario that could be used in further analysis of the impact of both irrigation schemes at a larger scale.

Nevertheless, the concept of 'Irrigation system performance' is in continuous evolution. There is a need for a generic assessment framework in this sense. This requires methodological improvements of evaluation and new performance indicators (Chaponnière et al, 2012). In this sense, this study aims to develop a generic grid of indicators useful to evaluate farmers' perceptions through an opinion poll and further adaptations to cope with the problems identified.

2.3. FARMERS' PERCEPTION

It can be stated that when evaluating a determined system composed of diverse actors, there exists a pluralism of criteria and perspectives that all put together make up its reality. They are multiple faces of one truth, and each one is characterized by a different set of circumstances that build up and shape their point of view, the prism through which each individual looks at things. Taking this into account, it is crucial to understand what dimensions composes each perception and how do they do it. This enables to integrate different visions together in a joint evaluation of the same system, in a holistic approach that aims to gather different opinions of the same environment.

Nevertheless, the task of breaking down any person's perception into basic dimensions that characterize each individual's rationale is complex and requires deep study. This research, far from aiming to analyze the nature of human perception tries to understand which elements make an influence on farmers' point of view towards irrigation systems, allowing gathering pieces of the same system. By doing so, it will be possible to understand the reality of the irrigation system's performance and more importantly: how farmers look at it, contributing to make explicit their main concerns, objectives and needs.

Firstly, it seems important to take into account that there exist, without a single individual, different perspectives depending on the circumstance to which they are confronted. Thus, we can speak of at least two types of perspectives: a visual/intellectual perspective, inherent to each individual, and a perspective of valuation. It can be assumed that when a certain person faces an evaluation process she or he takes then conscience of their perception, which was defined by Leibniz as 'apperception'. This concept, further developed by Kant, suggests that the breakdown of a synthetic unity into analytical elements is related to the self-consciousness of the individual, what in last term means a substantial different representation of the reality projected by the individual. Hence, it is possible that through the poll proposed in this study, farmers look at the irrigation schemes in a different way, being responsible to assess its characteristics and define them. Secondly, according to the theory explained above, human apperception is based on 'transcendental' and 'empirical' apperception, which is shaped by numerous aspects such as spiritual or religious, cultural, geographical, climatic, familiar or personal aspects. All these factors are interrelated, depending on each one interests, shaping farmers' perceptions. Thirdly, it also influences on farmers' perception the temporal factor. Interviews performed during the rainy season may not be as accurate as those done in the irrigation season. On the other hand, it can be stated that when an assessment of a past fact is performed, its utilitarian dimension is diluted, which can show the essential thought of farmers about any specific issue.

It seems logical that farmers and water agencies have different reasons to evaluate irrigation systems. The latter is mainly focused on "water conservation, improving 'beneficial' water use and reducing losses", whereas farmers focus on improving crop yields and the economic performance at farm level (Lord and Ayars, 2007). Furthermore, different perspectives are also found between farmers and system managers. As stated by Small and Svendsen (1990), there exist different values and priorities between both actors. This is referred mainly to the geographic scale of concern, the link between irrigation system performance and personal welfare and time horizons. Generally, the perception of individual actors involved in water management processes is characterized by five major perspective types: technical, organizational, personal, ethical and aesthetic (Mitroff et al, 1993; Courtney, 2001; Kolkman, et al, 2005). These types of perspectives build actors' knowledge determining the decision making process. This concept is crucial for understanding the differences between stakeholders when evaluating an irrigation system. Thus, actors at different levels within the same perspective type may have diverse judgments on the same topic, which can lead to conflicts over water management. However, farmers' perception has been traditionally screened out from the assessment process, which could lead to inefficient performances, given that farmers are the main users and thus key actors of irrigation systems.

But why is it specifically important to understand and evaluate from farmers' perception? Numerous studies prove that farmers' perspective towards issues such as soil fertility, salinity and pests differ from scientific evaluations because of the differences of objectives and approaches to the topics (Ali, 2003; Pereira, 2009). According to Lord and Ayars (2007), farmers have to cope with the following management variables: water supply, agronomic constraints, operations, environmental concerns and structural and economic considerations, what makes their point of view "more 'holistic' than those of researchers" (Desbiez*,* et al, 2004). These different dimensions build farmers point of view towards an irrigation system, which is crucial for the system itself as they influence on it directly through their farming and irrigation practices (Kielen, 1996). Thus, project evaluations should give to farmers' perception key relevance in evaluation processes and combine it with other stakeholders' points of view, in order to improve water management strategies and enrich the assessment (Guba & Lincoln, 1989; Sagardoy, 2007; Ghazouani, et al, 2009; Chaponnière, 2012).

However, including farmers into the evaluation process is not reduced to obtaining farmers general satisfaction with the system, but needs to analyze the degree of satisfaction for each part of the Irrigation System. For this purpose, qualitative information gathered from farmers' opinions (problems and solutions for the system and other comments) has been analyzed, being after contrasted to the quantitative information collected. For the latter, this study will be partly based on previous research done by Abernethy et al (2001), which provides a methodology to measure farmers' perceptions through the use of opinion polls to build an evaluation system.

Taking into account these concepts, it is necessary to categorize the actors involved in both schemes and define the links among them and with farmers that shape farmers' perception. Thus, it is possible to compare the context of farmers' perception at the Gumselassa irrigation scheme with the traditional one of Betmera. Through this comparison useful information is provided about the causes behind the different perspectives, facilitating the analysis of farmers´ evaluation of the system.

2.4. Methodological approaches in the Evaluation of Performances of Irrigation Systems

2.4.1. From experts' perspective

Traditionally, evaluation of performances of irrigation schemes have been undertaken mostly from a technical perspective, based on hydraulic and agronomic criteria (Bos et al, 2005). This technical approach is typically called 'top-down', given its analytic nature of study of a system by breaking it down into different sub-systems. From a hydraulic point of view, collective water management experienced diverse problems in different type of systems, which determined the strong role of technical criteria in the development of irrigation schemes (Ghazouani, 2009; Ferchichi, 2012). In this context, water balances have been at the core of the evaluation of performances, focusing mainly in the efficiency of water delivery in irrigation and in water productivity. Furthermore, efficiency of water conveyance has been deeply studied, developing indicators to analyze accurately water distribution and field application in order to minimize water losses and optimize its use. Other aspects of irrigation such as technical operations or the maintenance of the system have been remarked by technical experts to improve the conveyance of water and therefore the performance of irrigation schemes.

Concerning the agronomic criteria, experts have been focusing on the efficient use of water in relation to agronomic performance (Ferchichi, 2012). Much literature has been written aiming to increase the agricultural productivity from an efficient water use, specifically under the classical paradigm more crop per drop. Thus, water productivity was developed to complement the 'classical' irrigation efficiency, which focuses on the "nature and extent of water losses" and the efficiencies of storage, conveyance, distribution and application (Cook, et al, 2006, p.8). Augmenting water productivity is regarded as a key issue in order to increase agricultural production, being a concept dependent on agricultural factors such as type of crop, nutrient availability and irrigation application & cultivation techniques (Steduto, et al, 2007; de Wit et al, 1958; van Halsema, et al, 2011). Progressively, other dimensions as the social and environmental have been introduced in the evaluation of performances and impact of IS, provided their importance for its sustainability in the long term.

This circumstance led to a new approach in evaluation processes, taking experts to study IS from multiple dimensions in the so called multidisciplinary, transdisciplinary and interdisciplinary approaches. Among these approaches, the Rapid Appraisal Processes (RAP) provides a tool for undertaking diagnosis of IS from a physical and institutional perspective, aiming to set the key indicators of an IS necessary for its evaluation. According to Burt, C.M. (2001) this method contributes to facilitate informed decisions of a determined project concerning "the potential for water conservation", its weakness on its operation and management and potential actions that could be taken in order to "improve project performance". A parallel method to the mentioned RAP is 'benchmarking', a systematical process that aims to improve the performance of a system or organization by comparing current performance with previous and future objectives as well as with external similar organizations (Burt et al, 2001). Being framed as an external diagnosis, 'benchmarking' is traditionally used to measure outputs and impact of IS, which is done with reduced liability, given the fact that it uses secondary data and estimations instead of directly collected data (Kloezen et al, 1998; Molden et al, 1998; Ferchichi, 2012).

Other approach of evaluation is the one done by public administrations, which is based on experts' assessment under different criteria. The evaluation of performances of IS done by public administration normally evaluates them based on the efficiency of the use of natural and economic resources. These evaluations are then used to allocate financial resources and to determinate public policies (Bos et al, 2005), even though they have been typically assessed without taking into account their inherent differences at the social or economic level. However, this may differ at each country depending on the different policies implemented in each context. For the Tigray Region, traditional IS have been disregarded by public administration until the implementation of new irrigation schemes along the last 20 years, being the focus put on large-scale irrigation systems of state-farms. Hence, evaluation of performances needs to be done in numerous traditional and new irrigation schemes, which is currently being done under the new paradigm of evaluation from farmers' perspective besides the experts' one.

2.4.2. From farmers' perspective

Historically screened out of the evaluation of IS, farmers actually are essential actors of IS given their dual role as producers and clients of irrigation activities. Nonetheless, several authors pointed out the need to develop appropriate indicators to evaluate IS from farmers' perspective (Svendsen and Small, 1990; Gosselink et al, 1995; Abernethy et al, 2001), which led to a new trend of researches.

As a producer

To consider farmers as producers in the Evaluation of Performances of IS leads to frame their assessments within the Irrigated Agricultural System. In this sense, measuring farmers' level of satisfaction contributes to cover different dimensions of agriculture based on the real needs of each scheme, given that farmers are the main actors that deal with the practical problems of them. This recognition is crucial for improving IS's performances and understanding the key role of users in the formulation of irrigation policies (Maskey et al, 1996). Thus, participatory approaches have been developed to include farmers in the evaluation processes, conscious of the importance of the sustainability of IS in the long term. Among the most used, Participatory Rural Appraisal (PRA) provides a useful tool that based on interviews can be used to collect farmers' perspectives and other rural actors (Abernethy et al, 2001). On the other hand, PRA requires a sampling method that includes a large part of the rural population to avoid the concentration of answers on a single perspective, particularly of rural leaders (Ferchichi, 2012). Through surveys that sample a sufficient number of actors to be representative, differences of perspectives among farmers can be extracted and analyzed. By doing so, it is possible to understand better the features that influence on the perception of farmers' constraints as producers, helping to determinate new paths for tackling their problems and proposing solutions, contributing therefore to improve IS's performance. However, PRA not always succeed to determine the main problems faced by producers, being rather a means to obtain their level of satisfaction about determined objectives (Jinapala et al, 1998).

AS A CLIENT

In contrast to the vision that regards farmers as producers, looking at them as users of the system and therefore clients that receive a service places the evaluation in the Irrigation System scale, taking into account just issues related to Water Quality Service (WQS) and Source of Water. Being this system traditionally evaluated based on reliable data about water distribution, the experienced difficulties in many irrigation schemes concerning inadequate use of measuring devices has led to a change in the method of evaluation. Hence, numerous authors (Chambers, 1988; Small & Svendsen, 1990; Gowing et al, 1996) have pointed out the need to understand farmers' concept of a suitable water distribution. This shift from a technical to a more social approach in the evaluation assigns a new role to the users of the IS. According to Small & Svendsen (1990), clients of IS look at the evaluation of irrigation performance through three types of measures: depth related measures (adequacy, equity and timeliness), farm-management related measures (tractability, convenience and predictability) and water quality-related measures (sediment, salt and nutrient content, temperature, toxics and pathogens). Their evaluation of these indicators can provide relevant information for policy makers and technicians. However, this requires a common understanding between both actors, provided that farmers prefer oral expression to assess the system (Ferchichi, 2012) and experts quantitative data. In this context, the method provided by Abernethy (2001) – further explained in the methodology – in which farmers combine the qualitative information with a quantitative assessment through a ruler gives a solution to this dilemma.

2.5. INDICATORS FOR SUSTAINABLE IRRIGATION SYSTEM MANAGEMENT

Sustainability of irrigation systems is a concept dependent on diverse aspects such as the users, water, infrastructures and the institutional concept. Furthermore, it can be stated that the different dimensions of irrigation determine the performance of the system, namely the social, economic, and physical dimensions. In this context, indicators used to assess performances of irrigation systems need to cover these dimensions in order to achieve an effective evaluation. Similarly, these dimensions need to be framed in the adequate systems of the irrigation process in which the evaluation is framed. Being farmers the protagonist of the evaluation, the following performances are considered in the study, from which several indicators will be chosen:

- Irrigation system: this system is mainly formed by two groups of indicators, namely Collective, internal process and management of WUA and Irrigation-utility service to the farmers. For the former, indicators like rules and norms, participation, decision-making, membership feeling, interpersonal trust, group atmosphere and empathy are included to assess the system. The latter is evaluated through indicators such as water quality, adequacy, timeliness, tractability, predictability, equity and flexibility. In the evaluation, it is necessary to specify if it is referred to the actual year or preceding years, current needs or potential needs, or any other issue that influences on building a common understanding of the system between the interviewer and interviewee.

- Irrigated agriculture system: two families of indicators form this system: Farms' means of production (concerning resources) and Irrigation productivity and profitability. The first group includes water supply, labor, equipment, land-holding size, land-hold quality and transport among other indicators. The second one encompasses indicators like cropping intensity, rotation, production, pests, fertility and value of agricultural production.

- Agricultural economic system: this group is mainly characterized by the so called group of indicators Farms' external condition. It includes indicators such as agricultural advice, marketing, credit, inputs and health, which attain to characterize the socio-economic dimension of irrigation systems.

2.6. WATER GOVERNANCE

Governance of irrigation systems is determined by the established political, social, economic and administrative systems, which influence on the development and management of water resources and the water service delivery. Water governance follows principles of equity and efficiency in the allocation and distribution of water resources. It stands for an integrated water management based on catchments, stressing the need to balance water uses in order to achieve sustainability in the social, economic and environmental dimensions. From a legal perspective, it requires a clear formulation, establishment and implementation of water policies, legislation and institutions that details water rights and prevents bureaucratic obstacles and corruption in the irrigation system. Finally, water governance needs a clear description of the roles of the actors involved in irrigation systems, including the government, civil society and the private sector. The definition of their responsibilities in terms of management and administration of water resources and services allows for a better dialogue and co-ordination of all stakeholders, enhancing plural participation and facilitating conflict resolution. Furthermore, the role of women needs to be considered as a key factor in water governance given its importance in achieving food security in large areas of developing countries nowadays.

Given the previously discussed top-down approach of irrigation management, which caused the failure of numerous irrigation schemes, new alternatives have been searched in order to manage efficiently and sustainably irrigation projects. Thus, beneficiaries' participation in the management and governance of irrigation projects is being fostered to attain this objective. This requires capacity building from farmers' side to introduce sustainable water resources management and services and participate actively in the establishment of appropriate policies and institutional contexts that facilitate adequate water governance. Moreover, building capacities implies developing knowledge and mechanisms for sharing stakeholders' experiences at multiple levels. Common platforms to share perspectives on water management issues at different levels, up to a global dimension, offer a new scope for participation and collaboration of farmers in irrigation schemes (Pahl-Wostl, 2008). Hence, collecting experiences of water governance models can be used to contrast their benefits and scale up useful practices to improve water governance. To achieve this objective, active organization of meetings between different WUAs and within a single one need to be organized, provided that all stakeholders are actively involved in irrigation management dynamics.

Chapter III. Logical Framework and Research Question

3.1. Logical Framework

Very often, irrigation system evaluation methods fail to meet the requirements of policy-makers and managers because they evaluate irrigation performance at a different level. This situation creates a gap between farmers and decision makers that leads to non-operational evaluation systems. The main cause of this is the lack of identification and analysis of the links between the purposes of the project, its objectives and the evaluation activities undertaken. Thus, identifying the causal mechanisms that link evaluable actions to the objectives is of key importance in an evaluation process (Bos et al, 2005). Hereafter, the logical framework of this research will be explained, defining purposes, objectives (and sub-objectives) and expected outputs, with the aim of defining clear causal correlations between the goals of the study and the evaluation principles. The use of a logical framework in evaluating projects enables to communicate its objectives clearly and simply, providing essential information that summarizes the key features of a project design. Once the basis of the logical framework is set, it will be possible to break down the main objective into an objective tree (CGIAR, 2006; Chaponnière et al, 2012) of sub-goals that can be directly linked to the indicators used to evaluate the performance of the irrigation schemes. Eventually, based on the indicators considered, the activities (inputs) needed to develop the research are formulated and detailed in the Data Collection sub-chapter.

3.1.1. Purposes

The main purpose of this research is to develop a generic methodology that can be used to analyze farmers' perception of constraints and needs of adaptation at plot level of the irrigation schemes of Gumselassa and Betmera, through the definition of a grid of indicators able to synthetize the point of view of farmers. Furthermore, this study aims to gain insight mainly into farmers' perspective towards irrigation services and community irrigation management, but also towards biophysical and economic conditions concerning the agricultural system.

3.1.2. Outputs

The output of the research will be validated information contrasting farmers' perception towards irrigation from two different communities of irrigators, testing in the field the methodological approach designed. By doing so, it will be possible to know what are, according to the farmers, the main constraints faced by both schemes, and which different innovations have been implemented by them in order to deal with the problems identified.

3.1.3. Objectives

The objective of this evaluation can be placed close to the extreme 'utilization-focused' of the continuum audit-oriented, research-oriented and utilization-focused evaluations, defined by Mackay and Horton (2003). Mainly, because one of the main goals is to provide useful information from users' perspective of both irrigation systems not only to farmers themselves, but also to decision-makers and relevant institutions involved. Thus, it is believed that this information can be used to support collective learning and further action that contributes to tackle the main issues identified by farmers. On the other hand, this research is partially research-oriented, as it aims to build knowledge on new methodological approaches to evaluate irrigation processes.

More specifically, this study's main objective is to evaluate the performance of irrigated systems at farm level. In order to enrich the results, it will be based on a comparison of two contrasted situations: the Gumsalassa irrigation scheme, which experienced "poor performances at the scheme level" since the construction of the dam (Eyasu, 2005; p. 210) and the irrigated area of Betmera, one of the oldest irrigation schemes in the region of Tigray. Therefore, it will be possible to analyze both perspectives at farm level and explicit different management, practices and its causes.

SUB-OBJECTIVES

1. To develop a generic grid of indicators that can be used to evaluate irrigation process for the levels that concern farmers' activities.

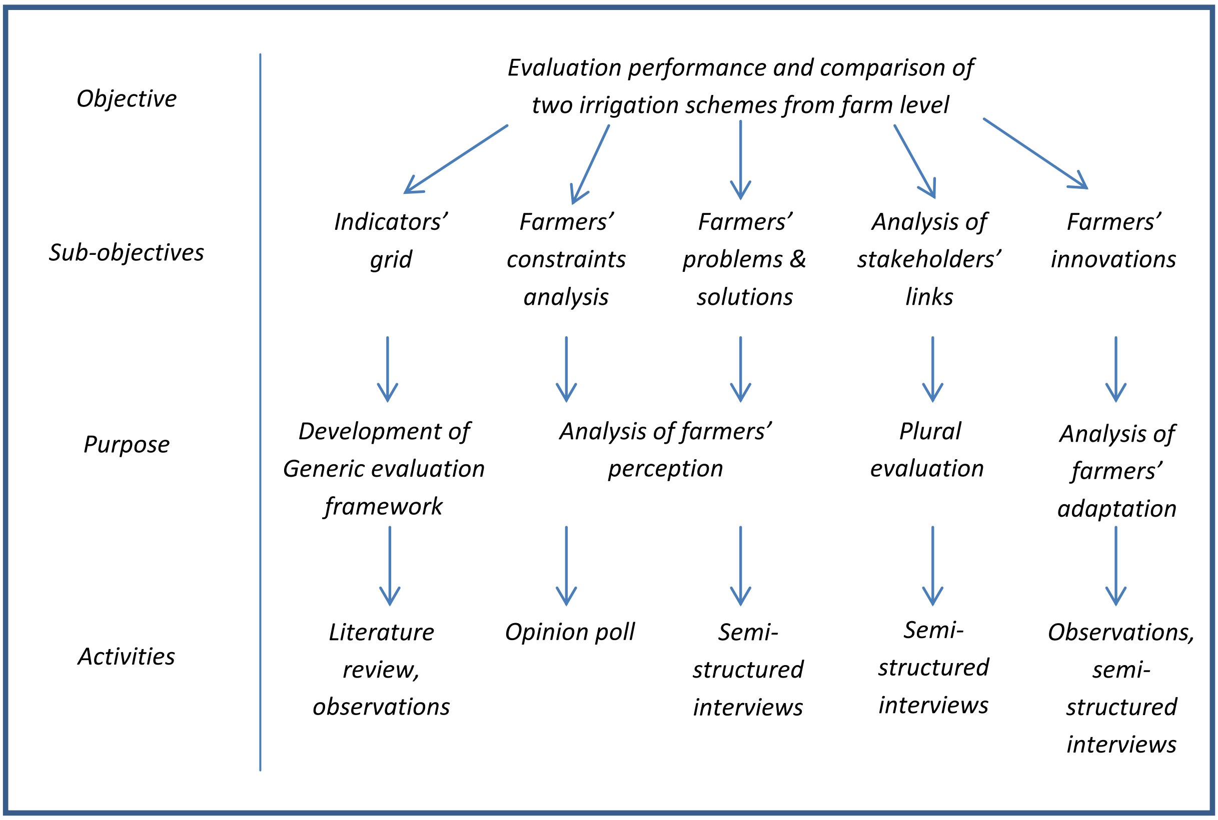
2. To identify and analyze the main constraints perceived by farmers, concerning water distribution, irrigation and agronomic management at the farm level, physic and socioeconomic constraints. This will allow the translation of farmers' perception into terms of choices of crops and practices.

3. To specify the main problems and solutions that farmers faced regarding the grid of indicators and link them to the adaptations undertaken by them in order to cope with these issues.

4. To analyze the interaction of other actors involved with farmers in the irrigation process with the objective of completing the evaluation of performance at the chosen levels and enriching the links that contribute to build farmers' perception

5. To identify the principal technical innovations implemented by farmers to face these problems and that could be supported and evaluated on the Gumselassa scheme in the frame of the project EAU4FOOD.

Fig.2. Objective tree



Source: Own elaboration

The construction of the logical framework is done through a collaborative approach in which evaluators are placed in an internal position. The stakeholders of the Irrigation System are involved in the evaluation process at different stages of the study, with the objective of obtaining their perspective and feedback on the system. It seems then logical that a complete research aiming to characterize farmers' perspective needs to involve them in the development of the logical framework and selection of monitoring systems used to evaluate the system. In this study, a group of representative farmers have been included in the selection of the grid of indicators, based on a primary selection done by the researcher. Furthermore, the interviews realized aim to get continuous feedback from farmers, asking for the adequacy of the poll design and about the inclusion of any other indicators that could be useful to evaluate the irrigation system.

As explained above, the description of purposes, expected outputs and objectives of the project allows the construction of an objective tree that sets the causal links between the goals of the project and the monitoring systems used (Girardin, P., 2004), which is detailed in Figure 3. The activities undertaken to respond to the objectives are further detailed in the chapter Data collection.

3.2. MAIN RESEARCH QUESTION

The main question addressed by this research is:

- What methodological approaches can be implemented in Evaluations of Performance of Irrigation Systems to effectively obtain farmers' assessment of it and what conclusions about its applicability can be extracted from its enforcement in two IS of the Region of Tigray, Ethiopia?

3.2.1. SUB-QUESTIONS

Once the main question has been answered, other questions need to be addressed in order to complete the research objectives, such as:

- What lessons can be learnt from previous approaches in Evaluation of Irrigation Systems?

- What method can be more appropriate in order to collect farmers' opinions about socio-economic and technical dimensions of IS?

- What groups of indicators are necessary to assess in a generic way IS and which specific indicators are susceptible to be included in the evaluation depending on the context?

- What are the problems encountered by farmers concerning the irrigation of their plots and what solutions have been implemented by farmers to cope with the existing problems?

- What innovations identified on both IS can be scaled-up in a different context in order to improve irrigation management?

- What limitations and opportunities enclose these innovations?

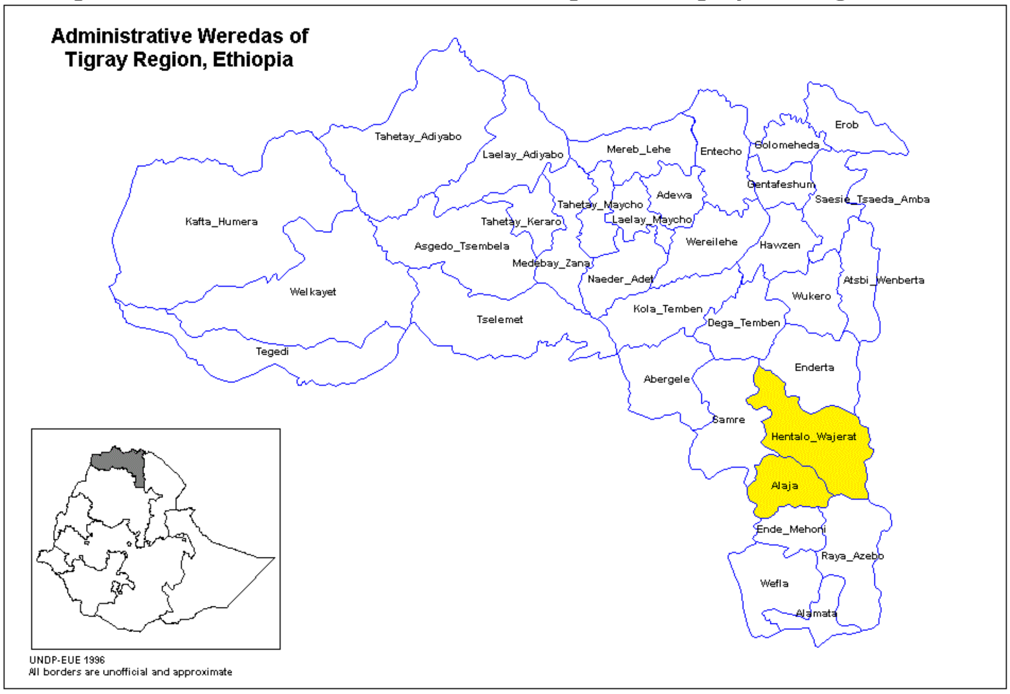
- Which are the successful aspects of the conceived methodology after its application in the field and which aspects can be improved to better evaluate IS from farmers' perspective?

CHAPTER IV. DESCRIPTION OF STUDY SITES AND METHODOLOGY

4.1. DESCRIPTION OF STUDY SITES

The study sites selected are located in two different Woredas, Hintalo-Wojirat and Emba Alaje (Fig. 4), both belonging to the Southern Tigray Administrative Area, separated by a distance of 29,5 km through the highway that connects Mekele with Addis-Abeba. In the Region of Tigray, annual average rainfall ranges from 980 mm on the central plateaus to 450 mm, registered at the north-eastern mountains. The eastern parts of the Region, where both study sites take place, have generally “less rainfall and higher annual variability of 49 % as compared to the other parts” (Kiflom 1997).

Fig.3. Administrative Woredas of the Region of Tigray, Ethiopia



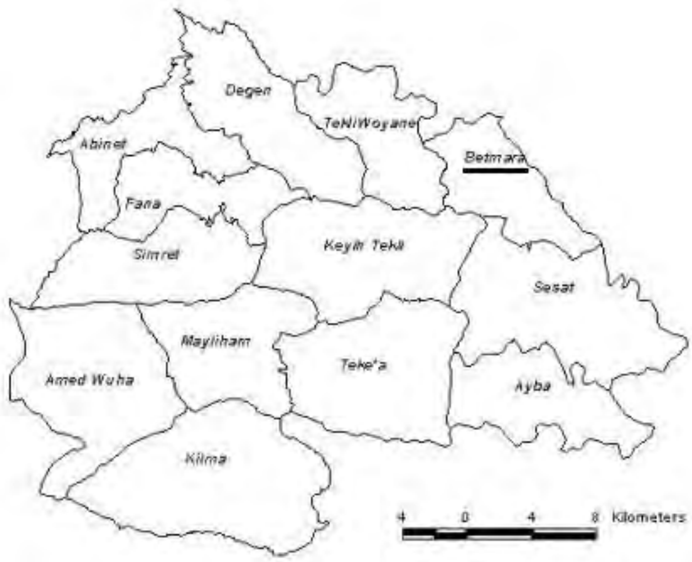
Source: UNDP-EUE

Numerous researches have been undertaken for Gumselassa’s irrigation scheme by Mekele University and other research centres, reason why there exists ample literature about the climatic, topographic and physical characteristics of its land and also water management. On the other hand, Betmera, one of the oldest IS in the Region of Tigray (Solomon & Kitamura, 2006), lacks research on its biophysical characteristics as well as in water management aspects. The inclusion of these two different sites can offer an enriching prospective through the contrast of performances of both, traditional and new irrigation schemes, even though the baseline data concerning both schemes is unequal.

4.1.1. BETMERA

At the irrigation scheme of Betmera two different associations are studied, the WUA of Shanfa Geladis and the WUA of Mai Tebatu, being part of the same catchment but managing independently the water that is conveyed from the source to the fields. Both sites are located in the Woreda of Emba Alaje, located at the south of the Woreda Hintalo-Wojirat, where the previously described irrigation scheme of Gumselassa is located. Irrigated agriculture is practiced in Betmera in the Zamra watershed, which totally covers a potential irrigable area of about 255 hectares, close to a seasonal river along which are placed several night storage that allow water collection, making possible irrigation during the dry season. Specifically, the irrigation scheme is located at 13°1’ N and 39°31' E, around the ketena Adirbaate of the Tabia of Betmera.

Fig.4. Map of the Woreda of Emba Alaje



Source: Fikru et al, 2005

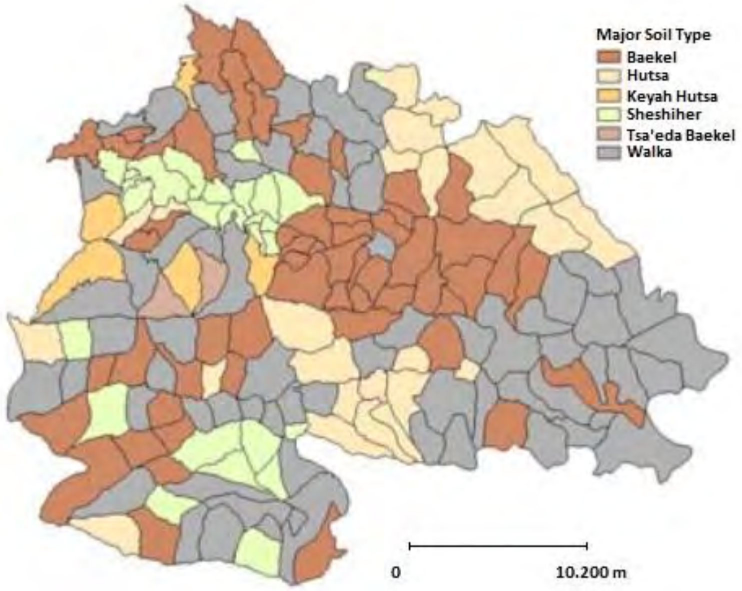
Climate

Rainfall and temperature data for the Tabia of Betmera is collected at the Adigudom Meteorological Station, the closest to Betmera-Hiwane traditional irrigation area, so the average annual rainfall recorded is the same as for the irrigation scheme of Gumselassa, 513 mm/year and temperature too, 19ºC. However, rainfall levels may reach slightly higher amounts in Betmera than in Gumselassa, given the strategic topographic position of Betmera, placed at a valley in the middle of a chain of mountains up to 3.949 m.

Soils

There exist four types of soils in the Woreda of Emba Alaje according to local perceptions: Walka, Baekel, Hutsa and Sheshiher. The three first soils were explained above, standing ‘sheshiher’ for a fine sandy soil. Specifically for the Tabia of Betmera, only one type of soil is identified by farmers: regosols (Hutsa), which only occupy 5% of Gumselassa’s command area. This type of soils is very common in arid zones, dry tropics and mountain areas, matching therefore with local traditional soil knowledge. More importantly, these soils are extensive in lands exposed to erosion processes, which is the case of Betmera, where the nature of the soil suffered the effects of water erosion through continuous flash floods.

Fig.5. Major local classification soil types



Source: Fikru et al, 2005

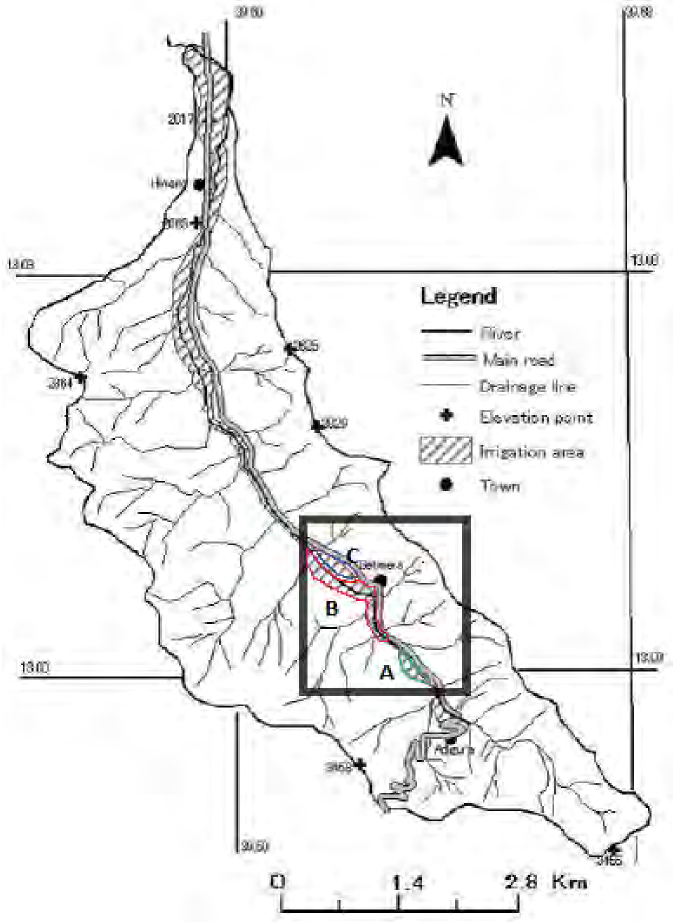
Hydrology

The irrigation scheme of Betmera is located in the Tekeze Basin, more exactly in the Zamra watershed. The river that supplies water to the fields collects water from the sources of a valley with little or no tree cover. The irrigation schemes of Shanfa Geladis and Mai Tebatu, are located along the right and left bank of the river, being therefore exposed to the erosion problems commented previously in Chapter II. Flash floods annually destroy the structures constructed by local people to manage the water for irrigation, causing serious not only economic but also agricultural problems. Currently, the irrigation schemes of Betmera dispose of three cemented-night storages and one traditional water storage pond (Mai Tebatu), made of stone boulders, tree branches, gravel, sand and mud. Other infrastructures present at the system are temporary river diversions, "earthen canals, wood troughs as bypass, underneath road crossing small tunnels" and "division boxes made of soil bunds" (Solomon & Kitamura, 2006). Temporary infrastructures have to be reconstructed by the community for each irrigation season (January-May) and (September-mid October), whereas during the rainy season (June-August) the maintenance of the scheme is reduced.

SHANFA GELADIS

The Water Users Association of Shanfa Geladis, Betmera, is a legal association of irrigators, recognized by the Ethiopian administrations and created 3 years ago. The command area usually covered by this association has been divided into two different pockets A and B – head-enders and middle-enders respectively –, which are actually formed by different areas. The pocket A is formed by the areas of Shanfa Geladis and Gera Gala. Pocket B includes the areas of Tamkatab, Gera Rastakhalai, Som Idja, Gera If and Gera Masano.

Fig.6. Zamra watershed and irrigation area in Betmera



Source : Solomon & Kitamura, 2006

Users of Pocket A and B receive water from the same source, Shanfa Geladis, which stores water from the spring of Faleg-emee. For the whole command area water is stored at different dams: Shanfa Geladis upstream, at the zone with the same name, made of stones and cement last year to resist annual flash floods. At Tamkatab there are two different dams, one made out of stones and cement for the right bank and one provisional made of mud and stones for the left bank. Water is conveyed for the right bank of this pocket by lined canals built by the SAERT. Downstream, at the area of Gera If is located the last dam of this system, made of concrete, supplying water for the areas of Gera If and Gera Masano, but empty during this season. Most of the water users of this command area are part of the WUA and water distribution is thus managed by the three abo-mais of the WUC. However, farmers from the left bank did not participate this year in the WUA given the scarcity of water, reason why they built a provisional dam and created a small system to manage water on their own. According to farmers and WUC, in seasons of high availability of water, farmers from Gera If and Gera Masano would also get water from the WUA, always from the source of Shanfa Geladis. This year, the command area goes until the area of Som Idja, leaving all plots downstream without water turn.

MAI TEBATU

The association of Mai Tebatu, also called pocket C in this study, is an informal association of water users taking water from the spring collected at the storage of Mai Tebatu. It is formed by around 20 farmers, even though this year due to the shortage of water only 13 of them were able to irrigate there plots. The plots receive water from a rudimentary water storage pond where animals drink, and that has the same source as a well of the village used for drinking purposes. This concurrence make water supply for this association even more complicated, due to the reduced size of the storage and to its deficient construction, which causes the loss of seepage water by run-off to the Zamra River.

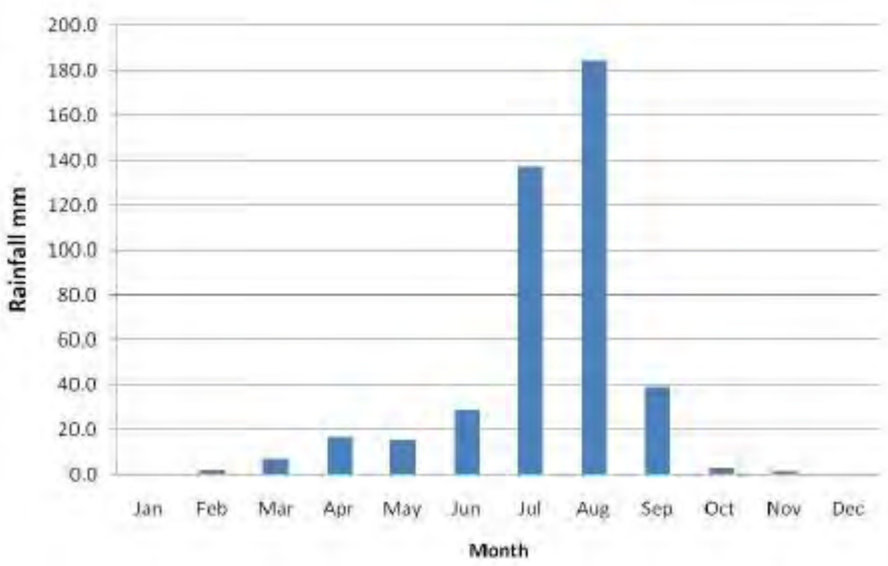
4.1.2. GUMSELASSA

The irrigation scheme of Gumselassa is located in the Woreda of Hintalo Wojerat, belonging to the Zone of Southern Tigray, Region of Tigray (Ethiopia). More specifically, it is geographically located between 13º13’ to 13º15’N and 39º32’ to 39º35’ E at the Tabia of Arra-Alemsegeda, about 35 Km south of Mekelle, capital of the region.

Climate

Concerning climate, Gumselassa experiences nine months of dry season and three months of rainy season, most of its rainfall occurring from the middle of June to the middle of September as it is represented in Figure 8 for the years 1975 to 2009.This data results in a mean annual rainfall of 513mm, reaching more than 180 mm of average in the month of August. The average annual temperature is of 19ºC, ranging from a minimum of 11º to a maximum of 27ºC with a mean annual temperature of 19ºC. The mean annual evapotranspiration is 1.486 mm (Tesfay et al, 2011).

Fig.7. Average monthly rainfall in Adigudem (1975 – 2009)



Source: National Meteorology Agency of Ethiopia

The above mentioned characteristics together with the altitude of the dam (1960 masl) make Gumselassa to be framed on the dry 'weynadega' agro climatic zone according to Ethiopia's Agro climatic zonation, being further explained in the Annex Agrarian Diagnostic.

Soils

It was designed for Gumselassa's catchment an irrigable area of 110 ha, from which around 80 ha are currently being irrigated. The catchment covers heterogeneous types of soils, mainly clay soils (58%) and silty clay soils (40%) (Nata et al,2004). More specifically, the types of soils, written in the local language into brackets, are distributed along the scheme as follows: vertisol (Walka) 30%, luvisol (Mekayih) 10%, cambisol (Baekel) 45%, regosol (Hutsa) 5%, mixture vertisol - regosol (Hutsa-walka) 10% (Eyasu, 2005).

Hydrology

The water supplied to Gumselassa's irrigation scheme is collected during the rainy season by run-off in the reservoir area of the earthen dam. It was constructed in 1995, at an altitude of 1.960 m. Irrigation started in 1997, distributing water to a command area between 1.960 and 2.100 m.a.s.l. (Eyasu, 2005; Tesfay et al, 2011). The estimated capacity was designed to be of 1.92 million cubic meters. Even though there are no current real measurements of the water stored, water capacity has been considerably reduced given the excessive sedimentation of the dam, blocking the spillway and risking blocking as well the outtake that supplies water to the command area.

Table 1. Gumselassa's Irrigation Scheme Baseline Data

Basic scheme data – Gumselassa	
Catchment area in ha	1.855
Reservoir	
- Area in ha	48
- Fetch length in m	1.200
- Capacity in million m3	1.9
Embankment	
- Effective dam height in m	11
- Free board in m	2.5
- Crest length in m	428
- Crest width in m	6

Source: Eyasu (2005)

Water is conveyed from the reservoir to the command area by gravity through a main steel pipe buried that crosses the earthen dam. It is regulated by two opening gates, being one of them out of service due to maintenance problems. Two secondary canals partly lined with cement supply water after a division box to the right and left bank, conveying water to tertiary field earthen canals and then to the fields. Other hydraulic structures such as drop structures and broad crested weirs are placed along the command area, used to convey and measure the flow. The responsibility of managing the water for irrigation relies in the Water Users Association (WUA) of Gumselassa, an association of farmers legally recognized by the Woreda that yearly elects its WUC, composed by two water managers (abo-mai), one chairman, one vice chairman and one secretary. The WUA also includes two guards that survey the command area. Between the left and right bank, a natural drainage conveys water from the seepage of the dam and the drainage of the plots to the downstream part, where farmers outside the designed command area use this water to irrigate their plots. These downstream farmers are associated in the informal WUA of Ayam Guile, managing the water of the seepage through informal rules and in some cases irrigating their plots also with groundwater. This is possible thanks to the shallow wells constructed by the PSNP, which provide farmers the possibility of irrigating during the dry season, requiring a pump to make effective irrigation.

4.2. DATA COLLECTION TECHNIQUES

The present study uses primary and secondary sources of data to collect quantitative and qualitative information. Primary data will be collected and analyzed on irrigation farming systems, socio-economy, institutional and management aspects from the farmers and other relevant stakeholders. This will be done through personal observations and an evaluation survey based on semi-structured interviews and an opinion poll. Secondary data collection is realized through literature review. Reports of the Gumselassa irrigation scheme done by the project EAU4Food are basic to gain insight about the context and objectives of the research. Nonetheless, different studies and articles on small irrigation systems in Ethiopia, evaluation of performance from farmers' perspective and past researches on Land and Water Management (LWM) in the region of Tigray are also reviewed.

4.2.1. QUANTITATIVE & QUALITATIVE METHODS

The irrigation scheme of Gumselassa has been object of numerous studies since the construction of the earthen dam in 1995, mainly because of the persistent problems encountered by farmers. Nevertheless, a significant part of these researches were based on quantitative assessments done from researchers' perspectives, that aim to identify, to measure and describe the main constraints of the irrigation system. However, the use of quantitative indicators for evaluation purposes is often "overstated" and not necessary "for strategic-level decision making" (Cashmore, M., 2004; Lee, N., 2006; Chaponnière, A., 2012). In this context, this research offers in two different ways a new perspective on the evaluation of the irrigation scheme of Gumselassa, complementary to previous researches undertaken in the scheme. Firstly, by analyzing the system's performance through qualitative methods such as observations and semi-structured interviews, this study aims to collect qualitative data with the goal of contributing to build methodological pluralism within the trans-disciplinary project that EAU4Food develops in the Gumselassa irrigation scheme. Secondly, the use of qualitative methods mentioned above will allow the analysis of farmers' perception of the Irrigation System, stressing insights from the field and enhancing the relevance of the assessment.

However, the core of the analysis of farmers' perception of constraints will be done using the method proposed by Abernethy et al (2001). In his study he stands for a methodology "that can be used to obtain quantitative measurements of the opinions of people" concerning "irrigation systems and other kinds of water development projects". This consists of an opinion poll formed by a net of indicators, further explained in the chapter Grid of Indicators. This grid contains a number of indicators that will be presented to the interviewees. For each one they will have to evaluate the performance on a scale from -7 (total disagreement) to +7 (total agreement). Thus, the assessment will be done from a quantitative approach. Furthermore, for each indicator the interviewee was asked about its main concern about it and if any, the main solution to tackle it from its point of view. This provides qualitative information to the poll, enforcing the methodological pluralism of the study, with the aim to answer to the third sub-objective of the study. It is an easy and rapid method, useful for obtaining perceptions and satisfaction levels among an ample range of farmer communities and other stakeholders. It provides a solid basis to support decision making since it deepens at the insight of users and permits to maximize the sample size. Eventually, it allows analyzing variations of opinions according to different types of actors of the system and within each actor to factors such as age, gender, experience in irrigated agriculture, location of the plot or educational level. In what concerns to the fifth sub-objective, farmers adaptation to constraints and identification and analysis of innovations, it will be done through observations and semi-structured interviews done with farmers. This will be realized in a second loop of interviews together with the interviews of key actors, after the first loop consisting on the interviews - opinion poll to farmers.

4.3. SURVEY DESIGN

The present study will be carried out through a community-level – Water Users Associations (WUA) - and key actors' survey in the irrigated catchment areas of Gumselassa and Betmera that include semi-structured interviews and an opinion poll. The type of survey used can be defined as an informal evaluation survey.

4.3.1. EVALUATION SURVEY

The objective of this type of surveys is to evaluate the eventual effects after an intervention. It is the case of this research, which aims to evaluate from the perspective of farmers the irrigation performance after the earthen dam of Gumselassa was constructed and thus allowed irrigation in the area. Additionally, the surveys at the irrigation scheme of Betmera will complete the study with the goal of contrasting the perception of farmers from both schemes and therefore understand their differences in terms of decision-making mechanisms and adoption of innovations.

4.3.2. INFORMAL SURVEY

Through these types of surveys information about perceptions, personal assessments of the systems and ideas about possible adaptations of Land and Water Management projects is collected, which is the case of this research.

4.3.3. OPINION POLL

The opinion poll aims to assess in a simple way stakeholders' satisfaction towards the current situation of the project. As explained above, it measures the degree of satisfaction (level of agreement) through a measuring stick in a scale that goes from -7 to +7. It provides a solid basis to evaluate the performance of the system from farmers' perspective, being adapted to contexts of high rates of illiteracy for its simplicity. However, in order to obtain unbiased information, several requirements need to be met. Firstly, it is essential to assure the anonymous condition of the informant, given that some farmers might be intimidated or doubtful about the use of the information. Secondly, keep the length of the pool short and specifically a reduced number of personal questions, always placed at the end of the interview. Finally, special effort needs to be done in the translation of the terms ‘I fully agree’ or ‘I fully disagree’ that mark both extremes of the stick, since these concepts may not be translatable to every language. This point can be extended to the translation of the whole questionnaire and the definition of each indicator, in order to achieve high quality results.

4.4. DATA SOURCE AND SAMPLING METHOD

In contrast to Abernethy’s et al (2001) research, this study uses a stratified random sampling method to select the farmers for the surveys. This sampling method is quite accurate and allows the comparative analysis of farmers’ perception according to different groups of interest, providing more information for this purpose than other sampling methods. Thus, for the irrigation scheme of Gumselassa the command area is divided into six strata: upstream (head-end farmers), middle (middle farmers) and downstream (tail-end farmers) and for each one right and left bank. Moreover, farmers of the scheme of Ayam Guile, using water from the main drain (seepage water) downstream of Gumselassa will be interviewed to have a more complete vision of the whole catchment. In total fifty farmers will be interviewed, seven from each stratum and within it randomly selected. For the irrigation scheme of Betmera 3 irrigation pockets were selected – upstream, middle and downstream-, undertaking for each pocket ten interviews to random farmers being in total thirty interviews.

They will be interviewed through a semi-structured questionnaire and an opinion poll that form the survey. For the case of key actors linked to farmers at each irrigation sub-system, they will be interviewed through a different questionnaire identifying their links with farmers. Depending on their knowledge of the systems they will be asked or not about some subsystems of the poll.

4.5. DATA ANALYSIS

Since opinion was being used to evaluate the system, investigations were undertaken in order to assess the reliability of farmers’ opinions. Statistical analyses were conducted to identify relations between the index of satisfaction and the specific farmers’ condition determined from either the determinant factors or the elementary indicators. At the end of the process, the results were analyzed thanks to feedback from a team composed of managers and local authorities.

The statistical analyses were performed in three steps. In the first step, the index of satisfaction was analyzed according to the determinant factors for each of the 19 integrative indicators using one-way analysis of variance (one-way ANOVA) and Fisher’s test. The least-square means of the index of satisfaction according to the determinant factors were compared according to Tukey's test at a probability threshold of 5%. In the second step, the index of satisfaction was analyzed using a general linear model (GLM) that combined one-way analyses of variance and two-order interactions. The non-significant determinant factors were successively removed until the model was only composed of significant variables according to Fisher's test at a probability threshold of 5%. The least-square averages of the index of satisfaction were compared according to Tukey's test at a probability threshold of 5%. In the third step, the index of satisfaction was analyzed according to the 114 elementary indicators using Student's two-sample t-test at a probability threshold of 5%.

4.6. CONCEPTION OF A METHOD FOR THE EVALUATION OF IRRIGATION SYSTEMS' PERFORMANCES FROM FARMERS' PERSPECTIVE

An opinion poll is a survey conducted with the aim of obtaining public opinions. Opinion polls are designed to represent the opinion of a certain targeted population, with the aim of collecting data close enough to the result that would be obtained through a census. This relation depends on the representativeness of the survey, which means the degree of precision of the data collection of a small group compared to the hypothetical data that would be obtained through the inquiry of the total population. Through this tool, researchers seek to be able to extrapolate the identified results by extracting the elements that allow for a generalization for larger groups. Thus, it would be possible to elaborate generic statements that attempt to have larger validity or even to formulate hypothesis or methods that may be applicable in other populations. This study, through the development of a methodology of evaluation based on literature review and its field application in two IS, tries to achieve consistent results, validated through the coherency of qualitative and quantitative information obtained.

Part of the requirements of the survey is to keep the interview as short and informal as possible, which allows larger size samples, to keep the interest of the interviewee at a high level and the possibility to undertake it anywhere (Abernethy et al, 2001). It seems logical therefore to keep the number of indicators for the assessment limited, so that it can be possible to carry out a short questionnaire and the poll, including a question about the main problem and solution for each indicator. For these reasons, the number of indicators - which will be further listed and described individually - included in this research is 21. They have been selected with regard to the main issues identified locally by the researcher through observations and informal discussions with farmers, water managers and other researchers involved in studies on the area. Finally, as it is explained hereafter, they are linked to the previously described objectives of the study.

Concerning the first point of the sub-objectives set, much literature has been written, aiming to establish the indicators required to assess the performance of Irrigation Systems. However, if it has to be done from the perspective of water users automatically many of those performance indicators have to be excluded and among the electable a representative selection needs to be done. This selection requires the previous identification of systems where indicators can be framed. Hence, in order to develop a generic grid of indicators that assesses effectively an irrigation process it is necessary to determine what subsystems form part of the process. According to Small and Svendsen (1992), the irrigation process can be divided into: five systems:

- The Irrigation System
- The Irrigated Agricultural System
- The Agricultural Economic System
- The Rural Economic System
- The Politico-Economic System

To this classification could be added the Environmental System, included in other classifications of system domains (Garcés, 1983; Levine, 1990; Gorantiwar and Smout, 2005; Bos et al, 2005) and of significant importance for the sustainability of the irrigation process.

4.6.1. CHOICE OF GROUPS OF INDICATORS

A generic method of evaluation has to take into account in which system/s it is framed. It seems logical that each project has different objectives and needs to be adapted to them. This study, whose goal is to evaluate the performance of the irrigated system from the perception of famers, sets the systems targeted according to the areas of interest identified by researchers and farmers' interest. As stated in the second sub-objective of the study, all actors pointed out towards agronomic and socioeconomic constraints; consequently, the indicators used to assess the performance of the system for this research belong to the irrigation system, the irrigated agricultural system and the agricultural economic system. Thus, researches aiming to evaluate IS performances from farmers' perspective need to identify first of all which systems need to be covered according to the different stakeholders and specifically according to the users of the system.

Table 2. Systems and groups of indicators used in the method

	The Irrigation System	The Irrigated Agricultural System	The Agricultural Economic System
Family of indicators	-Source of Water -Water Quality Service -Group Dynamics	-Quality of Soils -Crop Diseases	-Financial Resources -Marketing -Agricultural advice/tech. assist.

Source: Own elaboration

The three systems selected appear to be more related to farmers' activities given their scale of concern, reason why the two other systems would not be appropriate for this type of study. Within the systems, different groups of indicators can be chosen to evaluate the system. This study proposes the use of the families presented in table 6 for each system, being in total eight groups included in the poll. Concerning the irrigation system, the three groups proposed appear to be necessary for a complete evaluation, being the indicators adaptable to different contexts. The other two systems are formed by two families of indicators each one, whose indicators were chosen by farmers based on the indicators proposed. Depending on the IS studied, other families could be added to each system and some indicators can be added or excluded from the poll, being a flexible approach. Nevertheless, the groups of indicators included seem to be essential for a systematic assessment of IS.

4.6.2. CHOICE OF INDICATORS

Before describing the indicators of each system, it is important to remark that among the described systems' scale, different stakeholders interact with different perspectives of performance and objectives. Thus, "evaluation should be considered as substantially pluralistic" (Russ-Eft, & Preskill, 2001; Mackay & Horton, 2003; Chaponnière, et al, 2012). It is therefore essential to frame the actors at the different targeted systems and hence identify and analyze these interactions. This would enable to determine their influence on farmers' perception and to characterize the difference of assessments between them for the same grid of indicators (at each sub-system). The semi-structured interviews and inclusion in the poll for all stakeholders relates to the fourth sub-objective of the study. The previously-described activities and the construction of the indicators' grid to build the opinion poll explained hereafter would complete the activities considered for the set of sub-objectives of the research.

The choice of indicators for this grid has been done looking for a balance among the different dimensions that integrate irrigated agriculture. Thus, a grid has been developed and presented to a group of representative farmers chosen among the WUA of Gumselassa to discuss about the pertinence of its use in the poll. Through this meeting, several indicators were reformulated or changed by others, stressing the role for instance of technical assistance and Group Dynamics. The inclusion of farmers in the development of the grid of indicators is essential for achieving representative results from the poll, given that their perspective on the IS may differ substantially from researchers estimations based on benchmarking or exploratory interviews.

4.6.2.1. THE IRRIGATION SYSTEM

As stated by Chaponnière (2012), there is normally in Irrigation Systems "a transfer of management responsibilities" from governmental institutions "to Water Users Associations and other types of organizations". It seems therefore logical that farmers (water users) are the principal targeted actors to evaluate the performance of this sub-system, since they are both stakeholders and decision-makers. Nevertheless, it is crucial as well to include, for instance, water managers in the assessment, since they are active stakeholders of the system. In the case of both irrigation schemes selected for this research, water managers are the so-called abo-mais, who are at the same time part of the WUC and farmers. Therefore, even though there is a transfer of management responsibilities, in order to complete the assessment it is necessary to include the point of view of some governmental institutions. However, the approach to obtain their assessment through the selected indicators requires previous identification and description of their links with water users and water managers and with the system itself. In the case of a high degree of transfer of responsibilities, their inclusion in the assessment would be limited to explicating these links. Concerning the lower governmental level (Tabias), irrigation responsibilities are transferred to the WUC and the DA's, being the last actor to include in the assessment is the Bureau of Agriculture and Natural Resources.

- Targeted actors: water users (farmers), water managers (abo-mais), DA's and Office of Water Resources.

All in all, the evaluation of performance for the Irrigated System will include the following families of indicators:

Source of Water

One of the first families of indicators that need to be considered for the assessment of irrigation performances is the characteristics of the source of water. This research will compare two schemes with different sources (earthen dam in Gumselassa and a river in Betmera). Therefore, it is important to know if the differences in the perception of the issues start from the source or come later.

1. Quantity. Refers to either the total volume or discharge of water available for the whole community of water users.

2. Quality. Stands for physical and chemical characteristics of the water source such as temperature, sediments, and content of salt, nutrients, toxics or pathogens.

Water Quality Service

This family groups indicators that enable to evaluate the Irrigation Service. They are of specific interest to farmers in terms of management of irrigation water. Commonly used for assessment purposes are adequacy, convenience, duration of supply, equity, flexibility, predictability, reliability, timeliness and tractability. Among them, the following indicators have been chosen taking into account the relevancy of them in both irrigation schemes, according to observations, informal discussions with key informants, literature review and finally by contrasting this indicators through a group meeting with 4 representative farmers.

3. Adequacy. Objective performance indicator used to assess the relation between the volume of water supplied and the volume of water demanded by the users.

4. Predictability. Refers to the degree of confidence in the time of water supply, appropriate specifically in irrigation systems with canal water distribution.

5. Tractability. Indicator that deals with the capacity of control of water service in order to apply it according to farmers' needs to the land. It is based on different concepts such as flow rate, pressure or speed flow.

6. Flexibility. Management indicator used to assess the capacity of the system to adapt water distribution according to the different needs of the users.

7. Equity. Objective indicator of social nature that measures the existence of same conditions for all the users in terms of access, volume and flow. This indicator is crucial in order to achieve good levels of performance at the whole system and particularly relevant in "traditional farmer-managed systems" (Levine & Coward, 1986), where equity influences in farmers' acceptance of water shortage.

Group Dynamics

The selection of indicators for Group Dynamics has been based on the study of Ghosh,S et al (2010) concerning Group Dynamics Effectiveness of WUAs. Among the indicators proposed in that study this research uses five of them for its relevance to assess the social, economic, legal and management performance of the collectives involved in irrigation.

8. Participation. Defined by Ghosh et al (2010) as the "involvement of a farmer in different WUA activities". This refers to inclusion in discussion, WUA's functions, interaction with other farmers and perception towards other users' participation.

9. Fund generation. Group's capacity to mobilize and manage funds that can be reinvested in benefit of the association and that assure its financial stability. It is achieved through the payment of the contributors for water charges and it serves to pay works of reparation and maintenances as well as for saving purposes for future casualties.

10. Social support. Measures the "stability of the WUA in its area of jurisdiction" based on officials' support on technical irrigation management aspects, facilitation in performing WUA's legal functions, "help and inputs from other line departments", links with other WUA's and "capacity building of WUA members on different aspects through training" (Ghosh, et al, 2010).

11. Group atmosphere. Similarly to 'Social support' it is assessed through five concepts: congeniality with in the WUA, capacity to deal with conflict, "avoiding unpleasant feelings", farmers' diverse interests and "satisfaction and harmony of members" (Ghosh, et al, 2010).

12. Operation and maintenance. According to Ghosh, et al (2010) refers to the "operation of the control system, repair and maintenance of watercourses and management of the irrigation system". In his study, defines further this indicator, being based on five statements, which include the agreement of farmers in fixing internal water distribution, "following a water-sharing process for irrigating crops, selection of specific crop patterns by all farmers in an outlet command, maintenance and repair of the watercourses, field channels", drainage works by the farmers' group and "maintenance of the irrigation system through the WUA's own fund".

4.6.2.2. THE IRRIGATED AGRICULTURAL SYSTEM

As it was described in the Categorization of actors, several stakeholders influence on the agricultural practices of the irrigation schemes of Gumselassa and Betmera. They are involved at this system either by providing technical advice, directly supplying inputs (fertilizers, pesticides, insecticides, etc.) to the farmers or building the necessary infrastructures to assure water supply for irrigated agriculture.

- Targeted actors: water users, DA's, Office of Agriculture and Rural Development, Office of Water Resources

Quality of Soils

This family of indicators is used to assess the physical and chemical characteristics of the soil. It is essential for the research since previous studies report key importance of soil constraints from farmers' point of view.

13. Soil structure. Refers to the physical characteristics of the soil as texture, permeability and porosity. It is useful to assess phenomena like waterlogging or compaction of the soil.

14. Fertility. Indicator for the assessment of the content of nutrients in the soil available to the crops.

15. Salinity. Evaluates the content of salts in the soil that limit the natural growth of the crops.

Crop Diseases

Family of indicators used to evaluate the pathologies and organisms (fungi, microorganisms, insects, etc.) that threat the normal development of the plants. Informal discussions with key informants pointed out the specific importance of the use of insecticides and pesticides, which was confirmed by the workshop done with representative farmers about the indicators chosen. Thus, the following indicator is used:

16. Insects & pathogens. This indicator aims to evaluate the prevalence of insects and pathogens together at plot level, with the goal of quantifying its importance and further detailing its main problem and solution to implement.

4.6.2.3. THE AGRICULTURAL ECONOMIC SYSTEM

The third sub-system of the irrigation process analyzed in this research concerns the socio-economic and technical dimension of irrigated agriculture. The stakeholders included in this system are the same of the Irrigated Agricultural System, influencing on the creation of the economic context for farming activities.

- Targeted actors: water users, DA's, Office of Agriculture and Rural Development

Financial Resources

The indicators grouped in this family enable the assessment of the economic situation of farmers. It is formed by the agricultural revenue, credits (for agricultural purposes or not) and the existence or not of off-farm income. The first one is mainly determined through the next group of indicators and the last one through the interview. Thus, this group focuses on credit conditions for farmers and capacity to accede to inputs.

17. Availability of inputs. Refers to the accessibility to optimal agricultural requirements such as adapted and effective fertilizers, insecticides or pesticides and improved varieties of seeds.

18. Accessibility to credit. Useful to assess the satisfaction towards the procedure to obtain a credit. It is based on the number of institutions that actually offer credit opportunities and on the degree of complexity of the process.

Marketing

The indicators grouped in this family refer to the marketing conditions of agricultural products. It will be completed through the semi-structured interview by defining the location of commercialization of the products as well as the inclusion in cooperatives or other collectives of farmers.

19. Adequacy of prices. Indicator used to evaluate the satisfaction regarding the prices for the crops sold at the market. Since farmers commercialize several types of crops, the poll evaluates the average situation for crop prices, being further asked about its stability and the weakest crop in terms of price, if any.

Technic Assistance

Finally, the last family of indicators included for the opinion poll aims to evaluate the performance of the technic assistants, in the case of this research the DA's. This group of indicators is directly linked to the Social Support (Group Dynamics) of irrigated agriculture. Nevertheless, given its key importance – according to farmers – in the irrigation scheme of Gumselassa, it was included at the end of the poll, in a specific group so that it could be discussed in detail. Among other type of indicators useful for its assessment such as accessibility, accuracy, adequacy, reliability or timeliness, the following has been chosen:

20. Accessibility. Indicator related to the availability of technical staff providing technical advice and the capacity of farmers to contact them on time, easily and on a regular basis.

21. Effectiveness. Refers to the relation between the expected and the actual results of the technical assistance.

4.6.3. RESTITUTION OF RESULTS

This approach is created through a participatory process that includes different points of views and covers a wide range of issues related to irrigated agriculture. For evaluating performances from farmers' perspective each indicator is included in the poll and discussed with the farmer, with the objective of obtaining contrasted information about the problems faced by farmers and the solutions implemented by them for the three systems considered. Furthermore, the innovations proposed by farmers as solutions are discussed in this method through a group meeting with key farmers, defining more precisely the limitations and opportunities that each solution offers. The main object of this meeting is to contribute to the modification on the approach of evaluation of irrigation schemes in both study areas, including farmers' perspective in the research of solutions to improve the performance of irrigated agriculture in both schemes. Furthermore, the restitution aims to build knowledge among farmers at two different levels: firstly, within the WUAs of each study site, through the achievement of common understanding of the problems identified and solutions proposed. Secondly, between WUAs of two different irrigation schemes by exchanging different points of view and management strategies that could enrich the conception of innovations.

CHAPTER V. RESULTS

5.1. SURVEY RESULTS

In this chapter the results of the interview are described, exposing different outcomes from formal and informal interviews, further discussed in the next chapter Discussion.

5.1.1. CATEGORIZATION OF ACTORS

Irrigated agricultural systems are complex structures (Coward, 1979) that require well-structured and developed organization. Different types of actors are involved in water allocation and distribution, conflict management, and operation and maintenance of the irrigation system. Moreover, these actors influence on the management and practices of the farmers and contribute therefore to build their perception towards irrigated agriculture. Thus, it seems essential that an Evaluation System based on the perspective of farmers requires previous identification and clarification of the links between all the stakeholders and of how these different actors influence the decision mechanisms of farmers. Many different groups have interests on IS at different scales and dimensions. According to Svendsen and Small (1990) all actors can be grouped in the following four categories: national economic planners, international fund agencies, irrigation system managers and farmers.

This research, performed parallel to another one based on an analysis of institutional arrangements in the same study sites, focuses on farmers as the main actor – client and producer – of IS. Thus, a typology of farmers in both study areas is developed in order to facilitate the analysis of the results of the opinion poll, whereas the other study focuses on the analysis of the other actors at the local and Woreda level. However, farmers interact with these actors in the performance of the system, reason why they are also characterized in this research.

FARMERS' CATEGORIES

For the elaboration of this farmers' typology several criteria and categories have been taken into account. The categories considered are four: structural characteristics of the farm, economic characteristics, water and agronomic management issues and demographic information. Each category includes several criteria that have been included in the interviews to classify farmers. They are grouped as follows:

- Demographic information: Age, gender, level of education and household size.
- Structural characteristics of the farm: Farm size, ownership, start of farming in the plot and geographical location of the plot.
- Economic characteristics: Off-farm income, use of credits and commercialization of the produces.

- Water and agronomic management issues: Experience in agriculture and in irrigated agriculture, participation in farmers' collectives, crop system (including rotation), use of inputs and irrigation practices.

In addition, other aspects such as livestock production have been researched through informal interviews, with the objective of better characterizing households' income and understanding better production systems in a holistic way and not only the IS.

The selection of these categories, covered by the survey, has been done to encompass all dimensions of irrigated agriculture. Hence, demographic information and structural characteristics of the farm stand for the social features of farmers, economic characteristics for the economic dimension and the water and agronomic management issues for the technical dimension. These categories and criteria have been analyzed for farmers of each study site, with the aim of identifying which farmers are more dissatisfied with the IS, which are more satisfied and what type of farmers are more prone to develop innovations or adaptations in irrigated agriculture to cope with their problems. Nevertheless, given the specific influence of farmers' status in water management it is assumed that this criterion needs previous detail in order to fully understand the results of this research.

Ownership

Even though the agricultural fields are property of the Ethiopian administration, there are land use rights for the farmers to whom each plot was assigned. Depending on the ownership of the plot, there are two type of status for farmers: owners and sharecroppers. Given the different perceptions that both type of actors have towards irrigated agriculture, their main characteristics are described here in order to better understand their point of view and assessment of the IS at the opinion poll undertaken.

- Owners. There are different types of owners, in this study they are classified depending on their involvement or not in irrigated agriculture. Firstly, there are owners that work their fields on their own. These owners are involved either in practical irrigated agriculture as well as in organizational and common management activities as active member of the WUA. Secondly, there are farmers who own the land but do not work in agriculture for diverse reasons (age, gender, other professional activity, etc.). This type of actor, involved in agriculture as owner of a plot, present two different behaviors: leave/abandon the plot or hire sharecroppers to work at his/her plot. For the former, there exist different causes behind the abandonment. Among them the most common are:

    - Disagreement with sharecroppers in the contract. In most of the cases the contract between landowner and sharecropper consists on a distribution of the harvest of one third for the owner and two thirds for the sharecropper, in which case the sharecropper is responsible of all production costs, including labor and purchase of inputs.

  - Decrease on the size of the plot due to other farmers' expansion. In some cases, the owner stopped working the land for one or two years and he/she found out later that their plots have been reduced considerably, making them non economically profitable anymore.

  - Physical problems that difficult agricultural activities. In some cases, farmers are unable to continue working their plots due to problems of quality service (improper design of the canals, lack of canal maintenance, etc.), salinity, waterlogging or nutrient depletion. These problems are sometimes important enough to prevent farmers from achieving profitable yields; therefore, they end-up working in other plots as sharecroppers and abandoning their fields.

  - Lack of interest on agricultural activities. Lastly, there are some farmers that have other sources of income and do not consider irrigated agriculture as an essential activity for their welfare. Normally, they finish selling or hiring the plot to sharecroppers, but there may be years of abandonment in the meantime.

  - Increasing cost of the inputs: Some farmers recognized to have abandoned their plots due to the high cost of some inputs, particularly fertilizers, which are mandatory for accessing to water. In other cases this fact has led to the appearance of black market for the acquisition of Urea and DAP.

For the second type, owners who hire sharecroppers to work the plot there are two types of owners: those who are involved in group dynamics and participate in meetings of the WUA and those who are completely disengaged from agriculture, leaving all responsibility to sharecroppers. In this sense, these two arrangements are of major influence in the results of the poll, given that their level of involvement in social or technical activities shapes directly their assessment over the system.

- Sharecroppers. This type of farmers can be grouped in two sub-groups, depending on the type of contract with the owner. There can exist two type of sharecropping arrangements, being the contract defined in Tigrinya as follows:

  - *Scissor*: This contract consists on a division of the benefits – the harvest – between the owner and sharecropper, normally of one third and two thirds respectively, as stated above. However, another type of contract is also practiced, in which both actors divide equally the costs and benefits of agricultural activities. In these contracts normally sharecroppers are not involved in group activities of the WUA, being the owner who assists to the meetings and the sharecropper who is responsible of the agricultural and water management, including the meetings for the distribution of water turns.

- *Kray*: By this contract, a farmer rents the plot to another one for one year, having the right to cultivate it for himself and profiting from the entire harvest. The prices, explained in the parallel research, depend on the size and quality of the plot, and in these cases the sharecropper is fully involved in irrigation processes, including normally WUA meetings about any aspect of the IS.

Nowadays, the number of sharecroppers in Gumselassa is much larger than the number of owners cultivating their plots, around three fourths, whereas in Betmera two thirds of the interviewees were owners, suggesting that the proportion of owners is higher than sharecroppers in this study site. This fact has direct influence in the assessment of the IS given the substantial difference of perceptions that exist in both type of farmers. Specifically for indicators referred to social support or agricultural management in the long term, some farmers pointed out that sharecroppers are not as concern as owners. They stated that sharecroppers may work in a determined plot for a reduced time, whereas the owner of the plot will work it longer and thinks more therefore in future perspectives.

Education

The present study considers three types of farmers according to their level of education: schooled, non-schooled and farmers with religious education. However, there exist different degrees for schooled farmers that weren't considered in this research. Ethiopia's education system establishes a process in which students need to pass an exam on a two-year basis in order to reach the next education step. Thus, through the poll many different levels of education are registered for schooled farmers, ranging from the second degree up to the tenth, degree, the maximum among interviewed farmers. Nevertheless, many farmers left school even before passing the exam due to the impossibility to pay their studies, reason why a vast majority of farmers coursed low levels (up to 4^{th} degree) and resumed their agricultural activities. All in all, it can be stated that these farmers achieved a sufficient level of education of reading and writing to have a different perception in comparison to non-schooled farmers or farmers with religious education.

INSTITUTIONAL ACTORS

Other actors involved in Ethiopia's irrigated agriculture are presented here, detailing their relation with farmers and their basic functions. Further descriptions of the institutional actors can be found in the parallel study performed by Hisberg A., *Understanding Institutional Arrangements of the small-scale Irrigation Management in Ethiopia. The case of Gumselassa and Betmera irrigation systems.*

Region – Ethiopian Administration Unit. The study area of this research belongs to the Region of Tigray. Within this unit is framed the BoW (Regional Bureau of Water Resource) organism, which influences on the rural economic system and environmental system, but does not have direct links with farmers' activities. In contrast, at regional level exists the BoA (Regional Bureau of Agriculture and Rural Development, which has influence on farming activities, providing credits for fertilizers to farmers through the Offices of Agriculture and Rural Development. Within the Regions exists different zones, being the present study located at the Zone of Southern Tigray.

Woreda – Ethiopian Administration Unit, smaller than the regions and zones. This research, developed in the schemes of Gumselassa and Betmera, is framed in the *Woredas* of *Hintalo Wajirat* and *Emba Alaje*, respectively. At the Woredas' level belong the Office of Agriculture and Rural Development and the Office of Water Resources and Regional Irrigation Command Committee, who influence directly on the irrigated agricultural practices through the supply of inputs and the management of water sources.

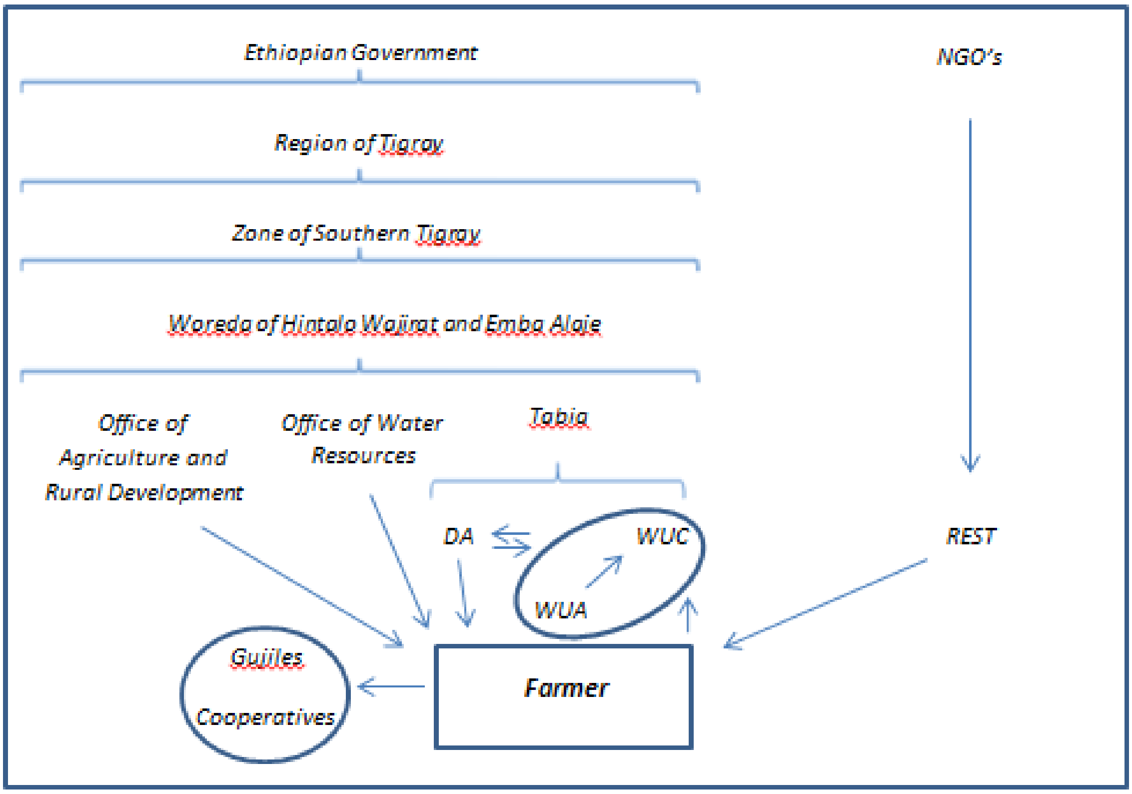
Office of Agriculture and Rural Development – It is divided into five sub-Departments: Extension, Livestock, Cooperative, Food Security and Natural Resources. Specifically relevant is the Extension Department, divided into sub-departments of Irrigation, Crops and Scaling-Up. The last one is, together with the Cooperative Department, responsible of the training program for model farmers. In this project they choose some farmers to adapt the innovations that the Office wants to implement, aiming to scale up these measures to the rest of farmers. Furthermore, the Extension Department is in charge of distributing the inputs for agriculture, specifically fertilizers, which are mandatory to buy for farmers. In case of irrigated agriculture, fertilizers' supply is compulsory in order to have water access, in which case the Woreda controls its purchase together with the WUA and Farmers' Cooperative for the case of Gumselassa.

Office of Water Resources – This organism of the Woreda is responsible of studying water supply sources, including localization and construction of infrastructures to make this water available. The experts working in this office cover different technical areas such as geologist, engineers, socio-economists or environmentalists.

Public Safety Net Program – Organism under the Woreda control that aims to assure health and food security to the inhabitants of each Woreda. For the Woreda of Hintalo-Wojirat, they are divided into four different Technical Committees: Public Works, General Management and Transfer Technical Committee, Task Force and Steering Committee. Each Technical Committee is formed by seven experts from different Offices of the Woreda: Agriculture and Natural Resources, Water, Mines and Energy Resources, Rural Constructions, Women Affairs and Health.

Tabia – Administrative unit that comprises usually five or six villages (Kuchets and Gots). In the case of this research the Tabias involved are the one of Arra-Alemsegeda (formed by the villages of Arra, Hidmo-Mahaidi, Hawatsu and Wombertaot) and the one of Adigudem (formed by the neighborhoods of Katana 1, 2 and 3) for the scheme of Gumselassa. For Betmera the responsible Tabias are Betmera, which groups the villages of Aleje, Genje, Terenabo and the katana of Adi Arbaate. In the organization of the Tabia concerning irrigation issues is framed the *Irrigation Command Committee*, which includes Development Agents and Water Users Committee (WUC). Farmers can consult this post if they have any doubt regarding the irrigated agricultural system.

Fig.8. Relation of actors with farmers (concerning economic, agriculture and irrigation management)



Source: Own elaboration

Development agents (DA) – Actors employed and dependent of the Woreda structure involved in the technical assistance of farmers for the agricultural systems. They work at Tabia level. In the case of Gumselassa, there are four DAs who work at the Tabia of Arra-Alemsegeda. They work at four different technical areas: Plant Sciences in Irrigation Schemes, Plant Sciences, Animal Sciences and Natural Resources. In Betmera, two DAs work together in Plant Sciences and Animal Sciences technical areas.

Gujile – Association of around 25-30 farmers within the irrigation scheme, normally from the same village. They have different objectives, which may differ among different tabias. Commonly, they are divided into 4 main fronts: health issues, good governance and security, education and agriculture. Concerning agriculture, the topics main topics treated are Soil and Water Conservation (SWC) practices, to organize and mobilize farmers to assist to meetings related to agricultural practices, discuss about effectiveness and adequacy of inputs, to contrast Irrigation and Water Management (IWM) practices.

Water Users Association (WUA) – Local institution formed by a collective of farmers responsible for the irrigation management of a determined irrigation scheme. Within the organization are included water users and several guards, responsible of the surveillance of water system. In both study sites the WUA is responsible to implement government's guidelines concerning the use of fertilizers, preventing from water access to those farmers who didn't buy fertilizers.

Water Users Committee (WUC) – Group formed within the WUA responsible of the management, organization and representation of the association. It is formed by five members: two water managers (abo- mai), a chairman, an accountant and a register. It is framed in the organism of the Tabias responsible of the water management issues

Abo-mai – Tigrinyan term that literally means 'father of water'. They actually are the managers of the Irrigation System and in both irrigation schemes analyzed they are also farmers with lands within the command areas studied.

Relief Society of Tigray (REST) – Non Governmental Organization (NGO) responsible of numerous irrigation projects in the Region of Tigray, investments on new irrigation projects and hydraulic infrastructures. They provide credit opportunities to farmers as well as technical assistance in determined situations.

Saving and Credit Association – Cooperative association present in each *kabele* (neighborhood). Farmers can be part of this cooperative by saving their income and they can take credits for diverse business, such as fattening programs or buying oxen to trade or plow the fields.

5.1.2. FARMERS' INNOVATIONS

In this section are presented the main solutions, adaptations and innovations already implemented or suggested by farmers to cope with the problems existing at both irrigation schemes. This conception of innovations has common and different points in both study sites, determined mainly by the type of problems registered, institutional context, farmers' perception and actors involved in the systems.

For the case of Gumselassa, Mekele University has been playing an important role along the past three years through different researches going on in the scheme. These concern crop protection, irrigation scheduling, soil fertility and salinity and fertility. For each category, a selection of farmers is involved either in working the plots either in the meetings organized to select the best option according to their criteria. Even though in these meetings farmers and researchers perform different evaluations, it can be stated that researchers have increasing influence on farmers' perception, introducing new ideas and concepts that are being spread at the whole irrigation scheme. In contrast, the irrigation schemes of Betmera have a lack of support from governmental and research institutions, which put on farmers the whole responsibility in what development of innovations is referred.

The main solutions suggested by farmers are exposed in Table 3 and Table 4, in which are detailed the WUA from where farmers suggested each specific solution for all the indicators included in the poll. These were selected based on the number of farmers providing similar answers – aiming to collect common perceptions among farmers –, relevancy of the answer and feasibility of implementation the suggested solution.

Table 3. Solutions provided by farmers for the Irrigation System

	Gumselassa	Betmera
1.Quantity	-Remove sediments of the dam	-Build larger storages -Diversify the sources of water
2.Quality	-Regulation on the use of water	-Install filters at the storages
3.Adequacy	-Build lined canals	-Build lined canals -Build larger concrete storages
4.Predictability	-Written register of water turns	-Build larger storages and lined canals -Diversify the sources of water
5.Tractability	-Build lined canals	-Build lined canals
6.Flexibility	-Written register of water turns -Increase farmers' participation in water management	-Closer control on irrigation activities from the Tabia
7.Equity	-Discuss openly about equity	-Discuss openly about equity
8.Participation	-Improve the communication -Administration involved in the meetings of the WUA	-Support from the Tabia to control the meetings
9.Fund Generation	-Increase farmers' participation on economic activities -Stimulate the cultivation of abandoned plots	-Group meetings specifically about WUAs' economic performance -Increase the productivity of the yields
10.Social Support	-Joint evaluation of irrigation performance (Woreda-Farmers) -Open participation to the meetings for model	-Improve DAs' support -Governmental support through construction materials such as cement, steel and pipelines
11.Group Atmosphere	-Equal water distribution	-Increase the quantity of water available for irrigation
12.Operation & Maintenance	-Build lined canals -Better governmental support to control the maintenance (DAs)	-Build lined canals

Source: Own elaboration

The solutions obtained at the survey respond to the current problems experienced by farmers in their performance. Thus, it can be observed that the main concern of farmers from Betmera is the infrastructures of the scheme, having an impact on the first five indicators of the poll as well as on the Operation & maintenance of the system. In contrast, farmers from Gumselassa have fewer problems related to water availability and infrastructures. They revealed to have problems on the social level as it is reflected in the solutions, by suggesting new regulations for water use and keeping written registers of the turns. In this sense, farmers claim for a clear definition of the use of water from the administration, enforcing new rules that set a determined percentage of the water distributed for irrigation and for washing, which would finish, according to some farmers, with the conflict between irrigators and women washing clothes at the canal. Concerning Fund Generation, farmers of both schemes claim for a higher involvement of farmers in WUAs' economic activities, stating that now they are alienated of these issues, which led to scattered assessments or directly abstaining to evaluate this indicator. More specifically, some farmers would like to be aware of what activities are performed with the money collected and some others increase the number of farmers involved in the WUC concerning economic management to achieve higher control of it. About the Participation, some farmers pointed out the need to have Woreda's support to encourage farmers to assist to the WUA's meetings, given that currently not all farmers are aware of the importance of participating in them. The solutions provided for three last indicators of Table 3 are again related, in the case of Betmera, to the problem of water availability, the key issue for these farmers. On the other hand, farmers from Gumselassa showed once again solutions of social nature, reclaiming better institutional support that takes into account their perceptions towards the irrigation scheme.

For the second block of indicators, significant differences are observed between the answers of farmers from both study sites, both for agronomic performance indicators and indicators related with economic performance. In the case of Betmera, farmers provided few ideas to cope with their scarce agricultural problems, mainly using compost to enrich the organic matter of the soil. For Gumselassa, different practices were suggested by farmers including better irrigation and agricultural practices and improved application of inputs at the plot level. These aim to solve the severe problems of waterlogging and salinity existing in the scheme, besides the extended problems with insects and pathogens that were of critical importance from farmers' perspective as showed in the results. An interesting innovation developed by an innovative farmer of Gumselassa is the application of 'chergued' an organic product made from tobacco leaves, used to tackle the diseases in onions, mainly 'mugella' – white common rot – and 'hamudia' – rust –.

In what refers to economic performance indicators, farmers from both IS proposed similar solutions, mainly easier conditions for individual credits and to raise the prices through community empowerment and commercialization of their products. It can be therefore stated that farmers of both study sites have the same problems on the economic dimension, given that the three indicators related to it have similar solutions. Furthermore, the indicators concerning technical assistance also register parallel ideas in both IS. In this aspect, farmers claim for a higher involvement of local governmental institutions in controlling DAs' work, both in terms of accessibility and effectiveness. Even though farmers had the same problems, farmers from Gumselassa appeared to be much more critical with DAs as showed in the results. This could be due to the fact that they perceive their problems (of social and agronomic nature mainly) solvable with technical support, whereas in Betmera farmers pointed out water scarcity as the main issue, and don't perceive that this could be helped through technical assistance.

Table 4. Solutions provided by farmers for the Irrigated Agricultural and Agricultural Economic Systems

	Gumselassa	Betmera
13.Soil structure	-Plow many times (mix the soil) -Use of compost, ashes and human organic waste -Use of furrows to manage waterlogging -Practice fallow	-Use of compost
14.Fertility	-Use of human organic waste, compost and other soil types -Alternative fertilizers available	-Use of compost and animal manure -Use different types of soils
15.Salinity	-Furrows to avoid waterlogging -Use compost, manure &urea	-Use of compost
16.Insects & pathogens	-Better DAs support -More inputs available -Use organic fertilizers	-Diversify crops cultivated -High application of water against 'hamudia' -Use of 'chergued'
17.Availability of inputs	-Institutions' support to decrease prices	-Group discussions with honey bee producers
18.Accessibility to credit	-Encourage credit institutions such as 'Saving & Credit'	-To facilitate individual credits -Adapt credit conditions to farmers' needs
19.Adequacy of prices	-Sell through cooperatives -Sell products stepwise (store them until prices get higher)	-Sell through cooperatives -Increase the water available to increase the quality of the crops
20.Accessibility of t. as.	-Increase DAs' presence at the field	-Increase Woreda's control over DAs
21.Effectiveness of t. as.	-Increase Woreda's control over DAs	-Institutional support to improve the technical assistance

Source: Own elaboration

However, not all solutions provided are innovative and not all innovations were provided as solutions by farmers, reason why other innovations identified through informal interviews and observations are also considered in the study. Thus, farmers of Gumselassa use regularly ashes from burnt organic waste in order to cope with salinization at their plots. Other measures that aim to tackle salinity problems concern the choice of the crop. For instance, an experienced farmer is cultivating rice in the scheme; a crop tolerant to salt that could be potentially introduced in severely affected areas. Furthermore, the choice of crops plays a key role in the agricultural management of farmers' plots. Leguminous crops like vetch are being increasingly used in farmers' crop rotation, due to the diverse benefits that it presents to cope with their problems. Firstly, as a leguminous it fixates nitrogen in the soil, contributing to improve the fertility of the soils. Secondly, this crop only requires one tillage work, saving labor for farmers. Finally, this crop only needs only three irrigation turns, which simplifies its management concerning water use and allows for an extension of water turns for other plots. Indeed, water and inputs management is of crucial importance in farmers activities. Some of the solutions and innovations suggested by them such as use of organic waste and compost or urea to fight 'hamudia' cannot be implemented because of its difficult management. Even though many farmers apply compost to fertilize their plots, they admit that the amount that they can produce and transport is not enough to achieve significant results. Thus, the meeting organized aimed to characterize the main limitations and constraints of the innovations identified, which allows to better understanding of the opportunities that they offer and the way they should be implemented.

All in all, it can be assumed that individual farmers who perform alternative agricultural activities are essential for the conception and introduction of innovations in irrigation schemes. Farmers' perception is shaped by traditional knowledge that in some cases make established assumptions. In this context, some farmers test all possibilities challenging this knowledge, as it happens with farmers that plant onions in the rainy season, fruit crops or cash crops, looking for alternatives of practicing agriculture that can improve their livelihoods. However, these innovative farmers complained about the lack of a common platform that includes all stakeholders to provide ideas and discuss about the problems that may occur. Specifically, they complained about the system of model farmers that doesn't promote innovative thinking, missing therefore a real platform in which farmers could reach together agreements on innovations or agricultural strategies.

5.1.3. FARMING TYPES

Taking into account the interviews performed and the statistical results for key criteria, with exception of a reduced number of innovative farmers, it can be assumed that agriculture has uniform characteristics within each irrigation schemes that don't differ much between both study sites, which is confirmed by the statistical results. Thus, it can be observed through the results of the research that the structural characteristics are similar, with similar plot sizes (around 0.25 ha) and start of farming. Ownership and geographical location have crucial importance for the evaluation of performance given their different perceptions of the system, but are not relevant enough to set different types of farmers. The agrarian system, detailed in Annex I, is defined as 'Small to medium scale crop-livestock production' for both study sites, being therefore a common element and a starting point for defining farmers' different typologies. Demographic information can be useful to analyze farmers' perception too according to gender, age or education, but their agricultural performance doesn't differ enough neither to establish different typologies. Thus, the types of farmers considered in this study are classified according to economic characteristics and agronomic management issues, given the diversity of practices in the economic and technic dimension. Looking into the economic dimension, there is a considerable amount of farmers that practice subsistence agriculture, commercializing the majority of farmers their products in the local markets or to traders. This choice influences directly in farmers' agricultural management and household activities, shaping the selection of the crops, use of inputs and credits, livestock holding and even household sizes.

Considering this, three types of farming have been classified for both irrigation schemes. The first type called A, formed by the majority of the farmers interviewed, includes farmers that commercialize their products, being these mainly the typical crops cultivated in the area. These farmers complement their agricultural production with livestock production, either for meat, eggs or milk production, with also some farmers who trade with oxen or donkeys. This group is characteristic for applying more inputs than the other groups in what refers to pesticides specifically. Household size is almost of six people in both irrigation schemes, and they showed a level of satisfaction of 3.3 in both study sites, which could be defined as medium. The second type of farmers considered is formed by those farmers who practice subsistence agriculture. They are characterized by the lack of income from agricultural activities, reason why most of them have a second source of income to cover their production costs or to buy goods such as sugar or oil for their living. Surprisingly, this group of farmers has in both study sites smaller plot sizes than group A, which could influence on the unprofitability of the commercialization of their products due to the small yields achieved.

Table 5. Types of farming at Gumselassa and Betmera

Characteristic	Type A	Type B	Type C
Main farm activity	Cereals, leguminous, pulses, livestock production	Cereals, onions, potatoes and vetch	Cereals, leguminous, pulses, fruit crops, cash crops, vegetables
Main source of income	Mixed farming	Off-farm activities	Agricultural products
Livestock holding	4-6 chicken, 1-3 donkeys, 2 oxen, 1-2-3 cattle	1-4 chickens, 1 donkey	4-6 chicken, 1-3 donkeys, 2-3 cattle
Farming approach	Business minded, mid-term investments, high use of inputs	Subsistence, low use of inputs	Business minded, long-term investments, medium use of inputs
Adoption-innovation propensity	Experimental	Traditional	Innovative

Source: Own elaboration

Normally, this type of farmers is stuck in a cycle of credits for purchasing fertilizers as the only input which is a common point with type A farmers. However they have different ways of paying back the credits, besides the fact that farmers type B receive help from the Safety Net for the subsistence of their household, formed by 4.6 people on average for both irrigation schemes, lower than type A. This suggest that their economic capacity is all in all lower than the first group, which through mixed farming are able to expand their households and achieve economic independence only through agriculture.

Finally, the last type of farmers included concern those farmers that commercialize high value crops or fruit crops besides their subsistence crops. Regularly, they keep cereal and vegetables for their households, commercializing crops such as coffee, avocado, mango, rice, oranges, gesho or khat for increasing their economic capacity. This farming strategy requires a long-term perspective to attain positive economic results, given the high initial investment required and the time needed to obtain good results in terms of yield. However, diversifying the crop production facilitates this farmers a secure source of income. They invest less time in plowing or applying pesticides given the nature of many of their crops chosen and their reduced problems of diseases compared to other farmers stuck in mono-cropping habits. In contrast, they proved to have innovative thinking on agricultural practices, applying higher amounts of own elaborated compost or using soils from different places. The time and money saved on traditional practices is used by them to explore alternatives that provide benefits in the long-term, which makes this type of farmers among the wealthiest of both irrigation schemes. However, their performance depends highly on water availability, meaning an important constraint specifically for the irrigation scheme of Betmera, where not all farmers have a secure water source each year.

5.2. STATISTICAL RESULTS

In this chapter the results of the opinion poll are exposed, analysing the outcome of the interviews and statistical analysis performed, which will be discussed in the next chapter Discussion, construing the results derived from the poll and informal interviews.

5.2.1. CHARACTERISTICS OF THE SAMPLES OF FARMERS INTERVIEWED

Based on the interviews performed and field experience, the main characteristics of the population sampled, both at Betmera and Gumselassa, are exposed below, describing the main features relevant for the study and distinguishing the links between them in order to fully understand the results obtained. In total, 78 farmers were interviewed and included in the poll, 39 at each study site. The figures for the number of farmers sampled according to gender, status, experience in agriculture and in irrigated agriculture are presented in Table 6, being further analyzed in the statistical analysis and the discussion.

Table 6. Characteristics of the population sampled

	Gender		Status		Experience in agriculture				Experience in irrigated agriculture	
	M	**F**	**O**	**S**	**1**	**2**	**3**	**4**	**<15**	**>15**
Betmera	29	10	27	12	8	15	8	8	18	21
Gumselassa	35	4	26	13	11	13	11	4	25	14

Note: In the column 'Experience in agriculture': 1=<15 yrs, 2=15-30 yrs, 3=30-45 yrs and 4=>45 yrs
Source: Own elaboration

BETMERA

The zones sampled at the study site of Betmera are the areas covered by the WUA of *Shanfa Geladis*, the informal WUA of *Mai Tebatu* (pocket C) and the new collective of irrigators of the left bank of *Shanfa Geladis* (pocket BL). Furthermore, for the statistical analysis the WUA of *Shanfa Geladis* its area has been divided into two zones because of its extension and different physical characteristics: *Shanfa Geladis* and *Gera Gala* (pocket A) and *Tamkatab*, *Som Idjo*, *Gera Rastakhalai*, *Gera If* and *Gera Masano* (pocket B). In table 7 are shown the main features of the farmers sampled for the whole system of Betmera, including the average values of their levels of satisfaction obtained.

Table 7. Characteristics and levels of satisfaction of farmers sampled at Betmera

Criteria	Class	Farmers sampled	Average satisfaction
Gender	Male	29	3.5
	Female	10	3.3
Status	Owners	27	3.4
	Sharecroppers	12	3.5
Experience in agriculture	<15 years	8	3.2
	15-30 years	15	3.6
	30-45 years	8	3.4
	>45 years	8	3.4
Experience in irrigated agriculture	<15 years	18	3.2
	>15 years	21	3.7
Zone	A	12	3.2
	B	12	3.9
	BL	3	2.0
	C	12	3.5
Educational level*	Schooled	15	3.2
	Non-schooled	20	3.5
	Religious	3	4.4

*Missing data from one farmer, 38 farmers are sampled for the educational level
Source: Own elaboration

Pocket A – Head-enders of *Shanfa Geladis'* WUA

This zone is cultivated by the head-enders of the IS, a group of farmers that from the sample results have on average 46.5 years old. Each household contains 6.3 people on average and householders have around 26.4 years of experience in agriculture, being only 9.6 for irrigated agriculture. The average date of start of farming in this area is 2001, which means that they have experience on other plots, mainly rain-fed on the nearby mountains. The level of education among these farmers is medium, having half of the interviewees gone to school and only one among them to a religious school.

Similarly to the other zones, the average size of the plots is 0.27 hectares, where farmers cultivate a wide range of crops: onions, potatoes, tomatoes, maize, cabbage, carrots, wheat, barley, teff and sorghum mainly. Half of the farmers interviewed perform a regular crop rotation of their crops, while the other half decide based on the amount of water available and through common agreement with their neighbors. Concerning the use of fertilizers, half of the interviewees use compost besides of the compulsory fertilizers in order to have access to water. Other inputs are barely used due to the conflict with honey producers, even though most of them use insecticides to protect their crops. An interesting fact of this zone concern irrigation practices, given that all farmers interviewed irrigate by furrows except one farmer that irrigates maize by flooding, being his other crops irrigated through furrows.

Nine out of the twelve farmers interviewed are using credit facilities from diverse institutions for the purchase of inputs or personal purposes. These include the World Bank, Farmers' Union, WUA, Tabia, REST and Combined Package, which is used for livestock production. Unlike other zones of Betmera, specifically C, only one farmer has an off-farm income, being the others fully dedicated to agriculture. Most of the farmers commercialize individually at the markets of Betmera and Hiwane, even though some of them also sell their crops to traders that collect the harvest at their plots to sell them at the market of Mekele.

Pocket B – Tail-enders of *Shanfa Geladis'* WUA

The average age of farmers cultivating this middle and downstream part is of 55 years old, the highest among all zones with seven years of difference. The experience of these farmers in agriculture is also higher on average than any other zone, 33.8 years, as well as the experience on irrigated agriculture: 23.2 years. Indeed, the start of farming in this area dates from 1993, previous to the other areas. In this zone, each farmer has on average 6.7 familiars to sustain in its household and the level of education is generally extended, having most of the farmers interviewed (eight out of twelve) gone to public school and only one to a religious school. However, schooled farmers of this group reached low degrees of education, being only one among them who studied beyond 4th degree.

The average size of the plots is the same as for the A zone, 0.27 ha, although the crops planted may be slightly more diverse in punctual plots owned by innovative farmers. These include the crops mentioned above plus other cash crops such as gesho, avocado, orange, rosmarinus, coffee and khat. Most of these farmers recognize to rotate their crops on a regular pattern, which means a difference with the other zones studied at Betmera. Nevertheless, the use of compost is lower here than in neighboring areas, being only three of the interviewees regular users of compost and using the others the mandatory fertilizers. On the other hand, the use of pesticides seems to be more extended, being more than half of the farmers users of insecticides and four of them also of other pesticides. Concerning irrigation practices, furrow and flood irrigation are similarly used in this area, being flood majority among the farmers interviewed.

The use of credits is balanced, being seven out of the twelve interviewees beneficiaries of a credit from the REST, Tabia or Farmers Union. In this area, credits are occasionally used to rent pumps to take water from the river to irrigate their crops, specifically farmers whose plots are not included in the command area during a determined year. Only two of the farmers from this area have an extra employment and four of them use the crops for subsistence purposes without commercializing them. Those who commercialize their produces do so mainly in Betmera, but also in Hiwane and even traders from Mekele.

Concerning the tail-enders of the left bank, pocket BL, only three interviews were undertaken, being not enough to make major statements on their physical and social characteristics. However, data collected points out equal features in the physical dimension, differing some social aspects specifically given the new conjuncture in which they are out of the WUA of *Shanfa Geladis.*

Pocket C – *Mai Tebatu*

Farmers practicing irrigated agriculture in this zone have on average an age of 47.9 years old, having each household 4.3 occupants. Except for two cases, all of the farmers interviewed have at least 22 years of experience in agriculture, being the average on 28.3 years and 15.4 in irrigated agriculture. However, two periods of land allocation in this area are observed: firstly during the years 1982-83 and secondly between 1999 and 2001. This comes from the fact that most of farmers have other plots, located at the terraces of the mountains, cultivated each year only during the rainy season. Among this association a larger number of women could be interviewed compared to the other, formal WUA, located upstream. Concerning the level of education, only three of the interviewees went to school, being one of them a priest who received religious education.

The size of the plots is generally 0,25 hectares for every farmer, with several exceptions done to optimize the use of land at specific places. The crops cultivated at the pocket of Mai Tebatu are quite diverse, including tomatoes, potatoes, maize, vegetables, onions, teff, wheat, beans, barley, peas and garlic. Nevertheless, the crops selected at each plot don't follow a strict rotation. Most of farmers decide the crop according to the quantity of water available at the storage during the dry season, being wheat, teff, beans and barley generally cultivated during the rainy season and peas during the short irrigation season starting in September. Concerning the application of inputs, all farmers use urea and DAP, using also some of them compost to fertilize their plots. However, the use of insecticides is very limited and other pesticides are restricted due to the conflict with honey producers of nearby areas, so almost nobody applies chemical products except herbicides at several plots. Irrigation practices at this pocket are diverse among farmers, who do not seem to have a common perception regarding this issue. Half of the farmers consulted assure that they irrigate through flood irrigation, whereas the other half irrigates by furrows.

In what concerns to the economic characteristics, the majority of farmers is using a credit. Three institutions are offering this possibility to farmers of this pocket: the World Bank, the REST and the Tabia. Since they are not a formal WUA they cannot get credit opportunities for the purchase of fertilizers through the Farmers Union and the WUA, so they directly get it from the Tabia administration. Thus, most of these farmers are using this credit for personal and agricultural purposes, but not directly linked to fertilizers. Some farmers have cattle, which is the main secondary occupation and some others trade with crops. The main market for farmers from this area is Betmera, even though some sell at Hiwane too due to the higher demand of crops and prices. The transport used is regularly donkeys to Betmera and car to Hiwane, selling their products individually at the market.

GUMSELASSA

Farmers included in the poll have on average 46 years old, with a household size for each one of 5.7 people. The average experience on agriculture for these farmers is 26.3 years and 11 for irrigated agriculture, which started for the vast majority when Gumselassa's earthen dam was constructed in 1996. However, some farmers obtained their plots later, reason why the average date of start of farming in this scheme is 2001. Almost half of the interviewees (18) didn't go to school and among those who did (20) six of them had a religious education. In table 8 are shown the average values obtained for each class of farmers sampled, further analyzed in this chapter.

Table 8. Characteristics of farmers sampled at Gumselassa per village and zone

Tabia	**Arra-Alemsegeda**			**Adigudem**	**Total**
Village	**Hawatsu**	**Hidmo**	**Arra & Wombertaot**		
U/R	5	0	1	0	6
U/L	1	2	2	1	6
M/R	3	2	0	1	6
M/L	1	2	0	3	6
D/R	3	0	2	1	6
D/L	1	1	0	4	6
Seepage	1	0	0	2	3
Total	15	7	5	12	39

Source: Own elaboration

According to the results obtained through the survey, the average size of the plots at Gumselassa is 0.23 hectares, being slightly lower than the theoretical standard size of 0.25. This happens given the struggles that exist for a certain number of plots that found their size reduced after the abandonment of their plots during a certain period, occurring soft readjustments of the fields by farmers on their own. These plots are cultivated with teff, wheat, red wheat and barley during the rainy season and maize, potatoes, onions, garlic, vetch, tomatoes and chickpea during the dry season. The fertilizers applied by these farmers are the mandatory Urea and DAP, being only a reduced minority – five farmers – users of compost to complement those fertilizers in the management of the plot. In what refers to the use of insecticides and other pesticides, most of farmers use this inputs to prevent their crops from diseases. Most extended products are Malathion, Finitrothion and 2.4D, even though other products of local origin or facilitated by Mekele University are being tested at several plots of the scheme. The main irrigation practice used by these farmers is furrow irrigation, with 22 users out of the 39 interviewees. Among the others, 12 of the interviewees use flood irrigation and the five remaining combine both techniques, most of them making furrows for onions and vegetables and flood for maize.

Table 9. Characteristics and levels of satisfaction of farmers sampled at Gumselassa

Criteria	Class	Farmers sampled	Average satisfaction
Gender	Male	35	3.0
	Female	4	3.3
Status	Owners	26	3.0
	Sharecroppers	13	3.2
Experience in agriculture	<15 years	11	2.9
	15-30 years	13	2.8
	30-45 years	11	3.7
	>45 years	4	2.9
Experience in irrigated agriculture	<15 years	25	2.9
	>15 years	14	3.5
Village	Hawatsu	15	3.0
	Hidmo	7	3.3
	Arra & Wombertaot	5	4.1
	Adigudem	12	2.5
Educational level*	Schooled	14	3.0
	Non-schooled	18	3.2
	Religious	6	3.3

*Missing data from one farmer, 38 farmers are sampled for the educational level

Source: Own elaboration

Concerning the economic dimension of the IS, 26 farmers declared to use a credit from governmental institutions (Woreda and Tabia), REST or Farmers' Cooperative, given the fact that the WUA is not able to distribute fertilizers this year. Most of these farmers use the credits for the purchase of fertilizers, being the main other purpose livestock production. Around half of the farmers interviewed (20) have an off-farm income which includes mainly traders, construction workers, guards and other jobs offered at the village of Adigudem. Finally, thirty of the interviewees commercialize their products individually at the market of Adigudem and nine of them use their crops to feed their households.

The reduced size of the sample of farmers taking water from the seepage (3) doesn't allow making general conclusions on their characteristics. Besides, the three farmers interviewed pointed out different agricultural approaches, organization of irrigation and even farm sizes (0.16 ha, 0.2 ha and 0.5 ha), which all together makes of this irrigation area a particular community in terms of water management.

5.2.2. ANALYSES OF VARIANCE (ANOVA)

The statistical analysis performed contrasted the levels of satisfaction obtained among the criteria of farmers' typologies purposed and the 21 indicators chosen for the study through a one-way analysis of variance (one-way ANOVA) and Fisher's test. Three scenarios were considered in the analysis, one for Betmera, another one for Gumselassa and a third one comparing both irrigation schemes. The aim of the analysis is to determine which criteria and indicators show significant differences for the three respective scenarios, determining relevant correlations between criteria and indicators on the levels of satisfaction and identifying the nature of the results (homogeneity of answers, analysis of perceptions and representativeness).

For the first scenario, which compares both irrigation schemes, the following criteria are detailed due to its representativeness: scheme, experience in irrigated agriculture, level of education, indicator, indicator per scheme and indicator per level of education. The second scenario analyses the irrigation scheme of Betmera, in which several criteria are relevant for the analysis in order to explain the variances: zone, irrigation practices, commercialization of the products, credit facilities, educational level and zone per indicator. Finally, the last scenario concerns the IS of Gumselassa, for which will be analyzed zone, experience in agriculture and indicators per zone. The detailed study of these criteria sets the basis for the discussion of the research, where the most important aspects identified are argued in depth.

Table 10. Significant and non-significant variables derived from the ANOVA

	Significant variables	**Non-significant variables**
Gumselassa and Betmera	Scheme, experience in irrigated agriculture, educational level, indicators per scheme, indicators per educational level	Gender, status, experience in agriculture, rotation, irrigation practices, credit facilities, marketing, age
Betmera	Zone, irrigation practices, marketing, credit facilities, educational level, indicators per zone	Gender, status, experience in agriculture, experience in irrigated agriculture, rotation, age
Gumselassa	Zone, experience in agriculture, indicators per zone	Gender, status, experience in irrigated agriculture, rotation, irrigation practices, educational level, credit facilities, marketing, age

Source: Own elaboration

5.2.3. ANALYSES OF AVERAGES OF INDICATORS ON BOTH STUDY SITES

The three scenarios revealed relevant results for the statistical analysis of the indicators considered, whereas significant results concerning each criterion may differ from one scenario to the other. When analyzing individually Betmera and Gumselassa, two criteria come up to be specifically significant for both: the location of the plot in the scheme ('zone') and 'experience in agriculture'. However, in the comparison between both irrigation schemes performed by the statistical analysis, the criteria 'zone', is not worth to be contrasted given that conclusions can hardly be extracted from an analysis of two different systems with different layout. It would be rather significant to compare both schemes as a whole in order to identify what factors are relevant at the system scale. Thus, the criteria regarded by the analysis of both IS include the criteria 'scheme', 'experience in irrigated agriculture' and 'educational level'. Concerning the selected indicators, they appear to have a significant correlation with the level of satisfaction when both schemes are compared each other and also when the educational level of the farmer is compared.

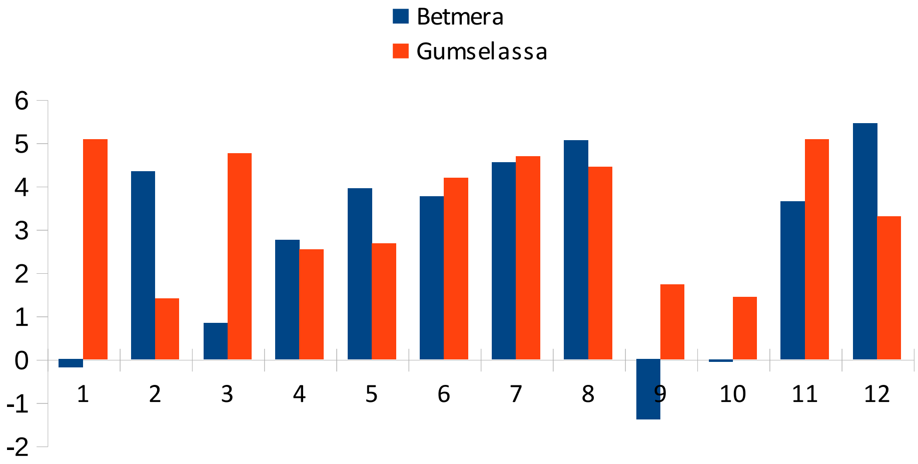
- **Scheme:** Among the key criteria identified by the statistical analysis, 'scheme' appears to be the less significant – probability of 0.18 –. However, several important facts can be extracted from the analysis at scheme level. Firstly, it is important to remark the heterogeneity of the group that forms the scheme of Betmera, formed by three different associations of water users (Shanfa Geladis, Mai Tebatu and water users of the left bank). Even if in Gumselassa's irrigation scheme there are also remarkable differences according to different users, they all belong to the same WUA, therefore having similar working conditions in terms of social support and economic group performance. Despite this heterogeneity, farmers from Betmera showed a slight higher average level of satisfaction (3.5) than Gumselassa's farmers (3.1).

- **Experience in irrigated agriculture:** When analyzing both irrigation schemes together, this criterion reveals specific importance, showing a significant diversity of levels of satisfaction depending on the years that one farmer has been practicing irrigated agriculture. Thus, farmers with larger experience in irrigated agriculture showed higher levels of satisfaction on average for the poll (3.7), whereas farmers with less than 15 years of experience on irrigation were less satisfied (3.0).

- **Educational level:** From the analysis of the levels of satisfaction from an educational perspective pertinent conclusions can be extracted. As a matter of fact there are a similar number of farmers that had education (38) and those who hadn't (38), including religious education (9) in those who had. Among these three groups, the highest level of satisfaction on average was provided by those who had a religious education (3.6). Other farmers with public education provided the lowest level of satisfaction on the evaluation of performance of both schemes (3.0), whereas farmers without any scholar education appeared to be in the middle (3.4). This fact may suggest that schooled farmers tend to be slightly more critical than the others with the performance of IS. Given the relevance of this criterion, further analysis and interpretation will be performed in the point 'Indicators/educational level', aiming to discover which indicators registered significant differences between the three categories of education proposed in this research and what are the causes that may be behind these differences.

- **Indicators per scheme:** The analysis of each indicator individually reveals relevant information that reflects the main characteristics of both irrigation schemes. Thus, the first indicator of the poll, Quantity, shows quite different results for Betmera and Gumselassa. For the first one, it can be observed that the amount of water available for irrigation is one of the main concerns from farmers' perspective, assessed with -0.2, whereas for Gumselassa, the evaluation was notably higher (5.1). The indicator Quality showed as well a significant difference in the assessment, being evaluated in Betmera with 4.3 and with 1.4 in Gumselassa.

Fig.9. Average levels of satisfaction for the Irrigation System



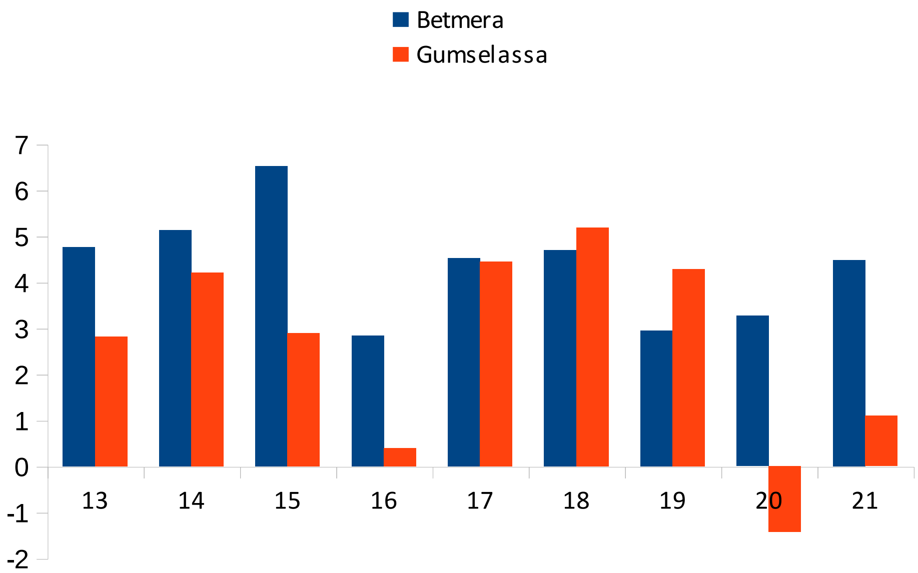
*1:Quantity of water; 2: Water Quality; 3: Adequacy; 4: Predictability; 5: Tractability; 6: Flexibility; 7: Equity; 8: Participation; 9: Fund Generation; 10: Social Support; 11: Group Atmosphere; 12: Operation & Maintenance
Source: Own elaboration

The group of indicators Water Quality Service presents relevant contrasts, given the different management practiced at both schemes. The indicator Adequacy, whose assessment is closely linked to the assessment of Quantity, reveals a lower level of satisfaction for Betmera (0.8) than for Gumselassa (4.8). Other differences in the management concern the Predictability of the system. Nonetheless, dissatisfaction of Gumselassa's farmers – expressed through qualitative information in the interviews – was not reflected in the poll results, showing at both schemes similar levels of satisfaction, 2.8 at Betmera and 2.7 at Gumselassa. Other fundamental difference between both schemes is on the Flexibility of the system, for which farmers from Betmera had a lower level of satisfaction. In cases of crops at risk farmers from Betmera have to wait to the weekly meeting to expose their cases, whereas in Gumselassa this decision is taken immediately due to the relative flexibility of the *abo-mais* set by the WUA. This fast response to provide water out of their ordinary turns is appreciated in Gumselassa, where farmers evaluated Flexibility with 4.2, while in Betmera they did with 3.8, at only 0.4 points of difference.

For the group of indicators Group Dynamics the indicators Fund Generation, Social Support and Operation & Maintenance showed interesting results at the statistical analysis. The first one reveals a clear difference, which lays on the fact that in Betmera more than one third of the interviewees – farmers from BL and C – belong to informal WUAs without any economic performance. Hence, the overall assessment between Gumselassa and Betmera is quite different, being assessed at 1.7 for the former and -1.4 for the latter. Social Support was evaluated negatively in Betmera (-0.1), while Gumselassa had a better assessment of this indicator (1.4). Finally, Operation & Maintenance presented a difference of 2.2 points between Gumselassa (3.3) and Betmera (5.5), the highest for this group of indicators.

In what refers to the indicators of agronomic performance, the main differences – besides the problems of erosion of Betmera – concern the indicators Salinity and Insects & Diseases. Farmers from Gumselassa evaluated Salinity with 2,9 and farmers from Betmera with 6.5, which matches with the qualitative information collected as well as field observations. However, the value for Gumselassa is still positive, what can be explained given the fact that salinity is localized in the middle part of the scheme and particularly in the downstream-left part, where the evaluation was sensibly inferior (-3.8). For the indicator Insects & Diseases farmers from Gumselassa did a medium evaluation (0.4), lower than farmers from Betmera (2.8) who have similar problems but in a lesser extent.

Fig.10. Average levels of satisfaction for the Irrigated Agricultural and Agricultural Economic Systems



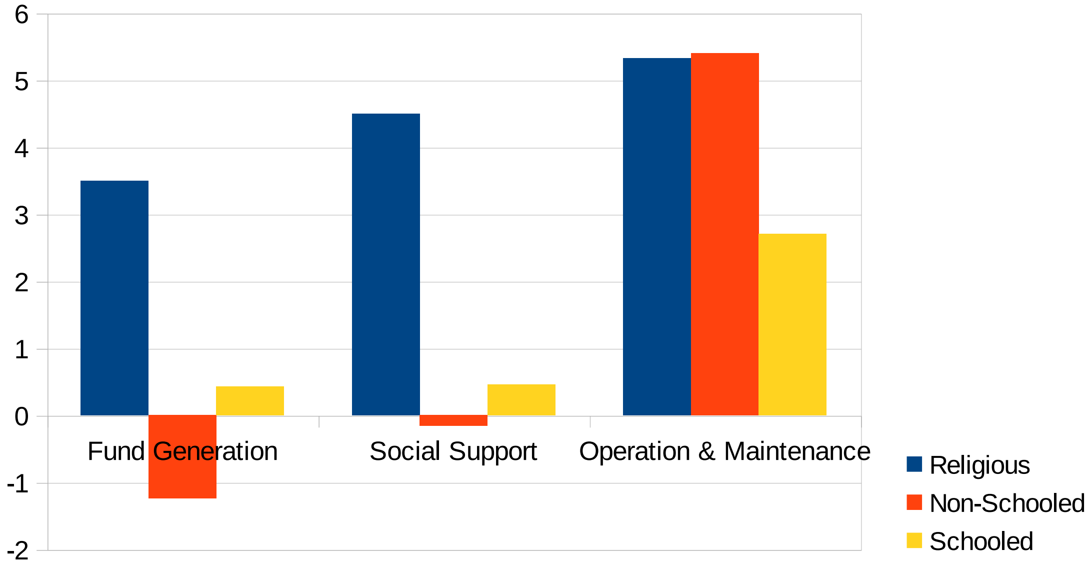
*13: Soil Structure; 14: Fertility; 15: Salinity; 16: Insects & Pathogens;
17: Availability of inputs; 18: Accessibility to credit; 19: Adequacy of prices;
20: Accessibility of technical assistance; 21: Effectiveness of technical assistance
Source: Own elaboration

Concerning the economic dimension, the Adequacy of prices was an indicator that showed slight differences between both schemes. Farmers from Betmera evaluated this indicator with 2.9, lower than farmers from the other IS, whose evaluation was of 4.3 points. Finally, indicators related with technical assistance to farmers got too disparate results. For the Accessibility of technical assistance, farmers from Betmera gave an evaluation of 3.3 while farmers from Gumselassa did with -1.4. Similarly, the evaluation of Effectiveness of technical assistance was much lower in Gumselassa (1.1) than in Betmera (4.5).

- **Indicators per educational level:** The three groups considered by the educational criterion: farmers that went to school, farmers with religious education and farmers that didn't go to school, show relevant results when they are compared at each indicator. Concerning the amount of water available and used for irrigation, Quantity and Adequacy indicators, farmers with religious education appear to be the most satisfied, with 5.1 and 4.6 respectively, being farmers with public education in second place – 2.5 and 2.8 respectively – and illiterate farmers in last place with 1.8 for Quantity and 2.3 for Adequacy. Next relevant differences can be found for the indicator Tractability, for which people that didn't go to school were the most critical with 2.6, followed by farmers who went to school (3.6) and finally farmers with religious education with 5.6. Also relevant within the WQS group is the Equity, that reveals a significant difference between farmers that didn't go to school (5.5) and farmers who did (3.6), being farmers with religious education in the middle with 4.2.

For the next group – Group Dynamics – three indicators are worth to be analyzed: Fund Generation, Social Support and Operation & Maintenance, being represented in Fig. 12. The first one was highly evaluated by farmers with religious education (3.5), in contrast with schooled farmers (0.4) and non-schooled farmers, who had a negative evaluation of it with -1.2. Similarly, the second indicator considered had in the religious group the highest evaluation (4.5) and in illiterate farmers the most critical (-0.2), being schooled farmers in the middle (0.5). For indicator nº12, which had a similar evaluation to Participation, farmers who went to school did the lowest evaluation (2.7), almost three points below non-schooled farmers (5.4) and farmers with religious education (5.3).

Fig.11. Comparison of Fund Generation, Social Support and Operation & Maintenance according to the educational level



Source: Own elaboration

Concerning agronomic performance indicators, the largest differences were found for Insects & Pathogens, for which farmers with religious education were quite critical (0.6), being schooled farmers moderately satisfied (2.6) and non-schooled farmers between both (1.1). The Availability of inputs had in schooled farmers its most critical group (3.4) in contrast to farmers that didn't go to school (5.3), having farmers with religious education an evaluation of 4.6. In what refers to economic indicators, the Adequacy of prices shows a significant difference among the three groups considered. Farmers with religious education got almost the highest value (6.4), whereas schooled and non-schooled farmers had an evaluation three points lower, with 3.5 and 3.1 points each one on average respectively.

5.2.4. ANALYSES OF AVERAGES OF INDICATORS AT EACH STUDY SITE

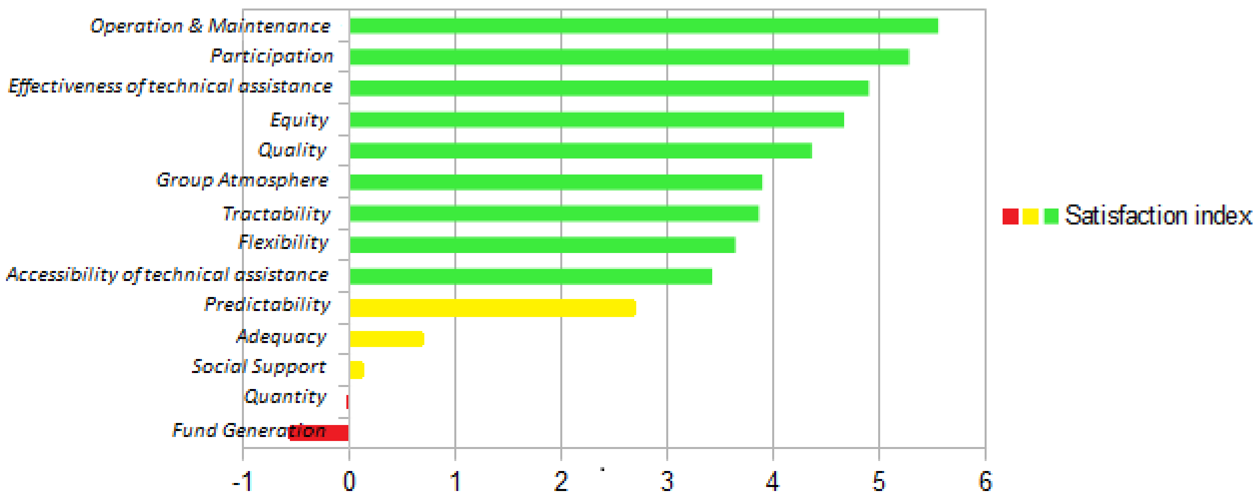
In this section are analysed the significant criteria identified by the ANOVA analysis, detailing the main features and levels of satisfaction of each criteria relevant for the study.

5.2.4.1. BETMERA

For the irrigation scheme of Betmera seven criteria were considered, since they all appeared to be significant variables according to Fisher's test, being below the probability threshold of 5%. These indicators include 'zone', 'irrigation practices', 'commercialization of the products', 'credit facilities' and 'educational level'. Moreover, the analysis of the levels of satisfaction points out significant differences among those farmers when comparing the indicators considered per zone.

Figures 13 and 14 show the levels of satisfaction of Betmera's farmers for each indicator, being the former for the Irrigation scheme level and the latter for Farm level. As stated above, farmers of this IS got higher levels on average in comparison with Gumselassa's farmers, which corresponds to the fact that 14 indicators were assessed above value three in the poll, providing a high average value in total (3.5).

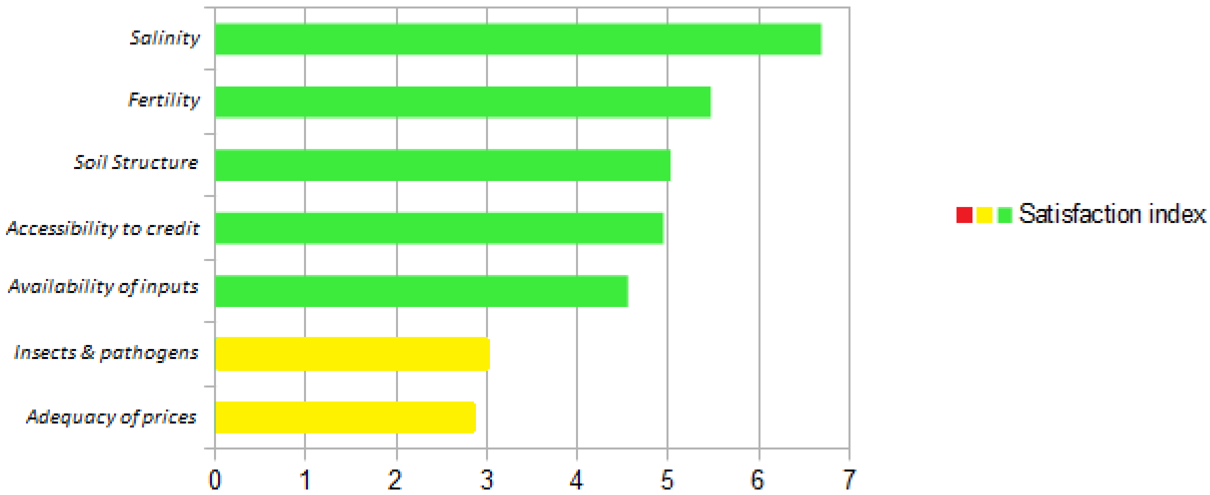
Fig.12. Levels of satisfaction at the Irrigation scheme level in Betmera



Source: Own elaboration

From Figure 13 it can be deduced that farmers of this IS have a strong sense of community and responsibility towards the irrigation scheme, given the high values provided for the Operation & maintenance and Participation at the meetings of the WUAs, both evaluated above five points in the poll. This is confirmed by the assessment of Group atmosphere (3.9), which got a lower evaluation due to some conflicts with water managers, pointing out that the atmosphere among farmers is excellent. Technical advice was positively evaluated in Betmera, appreciating much its Effectiveness rather than their Accessibility, even though the latter was assessed over value three in the poll too. Indicators of the group WQS had a medium evaluation, encompassed between the Equity (4.7) with the highest assessment and the Adequacy (0.7), being all positive. The Quantity of water available, linked to the Adequacy of water supplied from farmers' perspective, got an assessment of 0.0, being the main problem for a wide range of farmers at the system. However, Fund Generation obtained the lowest assessment (-0.6), which together with Social Support (0.1) were heavily influenced by the evaluation performed by farmers of Mai Tebatu, dissatisfied with this aspects in their WUA.

Fig.13. Levels of satisfaction at Farm level in Betmera



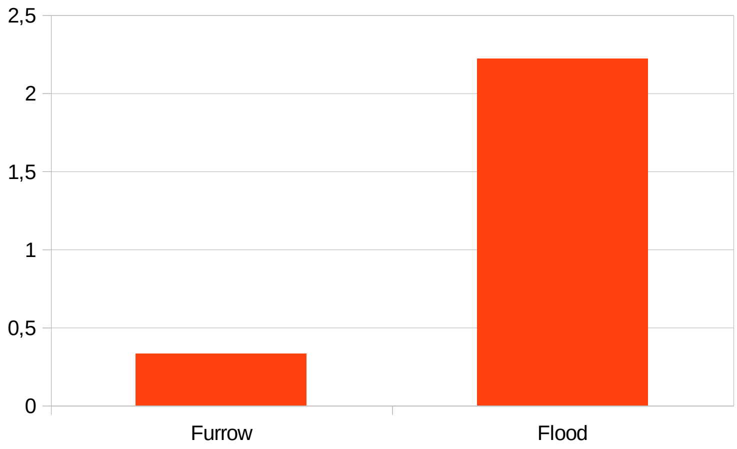
Source: Own elaboration

The assessments obtained for the Farm level were highly positive, being the lowest evaluation 2.9, obtained for the Adequacy of prices, more than one point lower than the evaluation done by farmers in Gumselassa. The highest value is registered for Salinity, whose problems are almost inexistent in this scheme. Despite the erosion problems expressed by some farmers in the area, Fertility and Soil Structure had high evaluations: 5.5 points and 5.0 points respectively. Among the agronomic performance indicators, Insects & pathogens got the lowest evaluation with 3.0, still higher than the correspondent value in Gumselassa.

- **Zone:** From the four groups considered in Betmera, farmers from the pocket B obtained the highest level of satisfaction (3.9), being farmers from the pocket C those with lowest (1.6). The group called C ranks second in this classification with an average of 3.5, being A the third one with an overall evaluation of the scheme of 3.3. Even though they all result in positive evaluations, they point out significant differences that need to be analyzed independently and per indicator in order to understand their causes and implications.

- **Irrigation practices:** Two irrigation practices are practiced in the schemes of Betmera according to farmers' responses and field observations: flood and furrow irrigation. A considerable majority of farmers perform furrow irrigation for the dry season for crops such as onions, tomatoes or potatoes, even though some of them irrigate by flooding half of their plots when they plant mainly maize as well. Furthermore, several farmers recognized that they practice furrow irrigation when water is scarce and flood when there is high availability of water, which suggests that furrow irrigation is in Betmera a measure which aim is to save water. According to the results provided by them, farmers that practice furrow irrigation are less satisfied with the performance of the irrigation scheme on average, having a level of satisfaction of 3.2. In contrast, farmers who practice flood irrigation evaluated the system with 4.5 points. Specific indicators of WQS like Adequacy show that farmers irrigating through furrows are less satisfied (0.3), whereas farmers practicing flood irrigation perceive that the amount of water applied is ore adequate to their Crop Water Requirements (CWR), registering a level of satisfaction of 2.2.

Fig.14. Farmers' perception of Adequacy of Furrow vs. Flood irrigation in Betmera



Source: Own elaboration

- **Commercialization of the products:** For this scheme there exist different options of commercialization that are grouped into two major groups: farmers who commercialize their products and those who practice subsistence agriculture. For the first group, the options are selling at the markets of Betmera, Hiwane or Mekele as well as selling to particular traders from Mekele, who collect the crops in situ. According to the results obtained at the opinion poll, farmers that sell their products are more critical with the performance of the IS (3,3) than those who don't sell their products (4.2). Even though the difference is smaller than one point, it shows relevant information for the study, specifically when looking at the location of these farmers and their irrigation practices. Concerning the location, most of farmers that practice subsistence agriculture are located in the B zone and to a lesser extent in the C zone. In what refers to irrigation practices, interviewees that don't sell at the market normally practice flood irrigation, with some exceptions that use furrow for specific crops, which links this criterion with the marketing of the products.

- **Credit facilities:** As it was described above, different institutions offer credit facilities, which are used by most of the farmers interviewed (27). They show a slight difference between both types of farmers for the average level of satisfaction: 3.3 for those who have credits and 3.9 for those who don't, meaning that farmers involved in credits might be more critical than those who don't.

- **Educational level:** Concerning the level of education, the group with the highest level of satisfaction at the poll were farmers with religious studies (4.1), followed by non-schooled farmers (3.6). The group with the lowest assessment was schooled farmers with 3.2 points.

- **Indicators per zone:** Relevant facts and conclusions can be extracted from the statistical analysis when looking at each indicator and comparing the results for the four different groups considered. Thus, below are analyzed the most significant results for each group.

Pocket A – Head-enders of *Shanfa Geladis'* WUA

The level of satisfaction obtained from the poll among farmers of this pocket (3.3) was the third one out of the four zones studied at Betmera. Despite the fact these farmers belong to the same WUA as B, they assessed the system below them (3.9) pointing out significant differences in terms of Water Quality Service and Marketing overall. For the former group, farmers from A showed lower levels of satisfaction for all indicators except for Flexibility. Particularly relevant are the results for Tractability, that show a two point difference between head-enders (3.2) and tail-enders (5.2). On the other hand, Flexibility was valued in the A zone at 4.6, whereas B was assessed with 3.3. This indicator related to management is linked to the indicator Predictability, which was assessed with the lowest value among all farmers by head-enders (1.3), suggesting that high flexibility has an impact on the predictability of water supply. Finally, higher levels of satisfaction were registered for the Availability of inputs in A (4.8), in contrast with farmers from B (2.5).

Other relevant figures are the results for the indicator Adequacy of prices, which gave evidential different values for head (-0.1) and tail-enders (5.5). In this sense, it is interesting to look at the marketing of the products of each farmer. Five out of the twelve farmers interviewed at B don't commercialize their products, whereas all farmers from A do. This fact enhances the importance of understanding farmers' perception in order to analyze the assessment. When compared to the left bank irrigators of Betmera and Mai Tebatu, it can be observed that farmers from A are satisfied enough with the indicators of Fund Generation (1.8) and Social Support (2.6), being the highest values on average, whereas farmers from BL and C register negative values for both indicators: -3.0 and -4.0 for irrigators of the left bank and -4.5 and -3.6 for farmers from Mai Tebatu respectively. However, even if these values are still positive, they are lower than the average of all indicators, which helps to identify the whole group of indicators Group Dynamics as an important dimension of water management that may differ significantly according to farmers' perspective.

Pocket B - Tail-enders of *Shanfa Geladis'* WUA

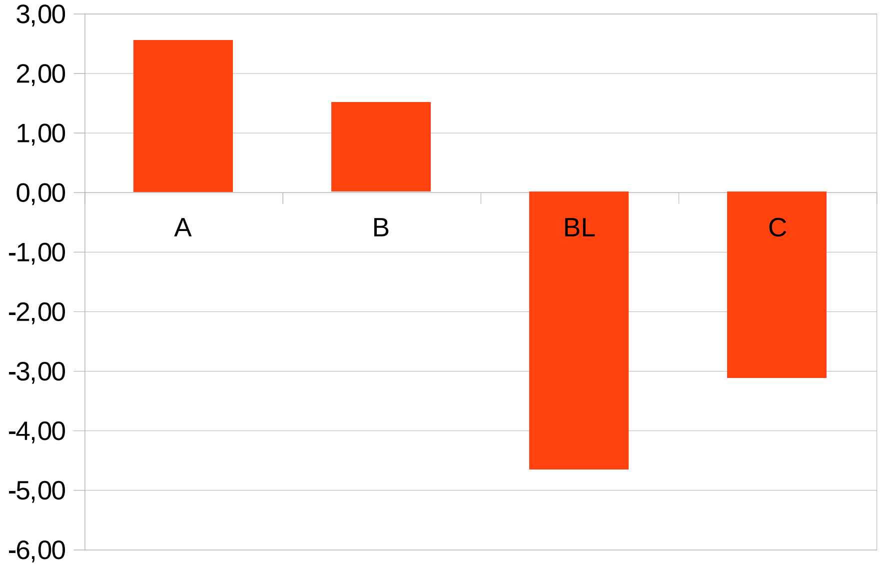
As stated above, farmers from the so called pocket B of Betmera reached the highest level of satisfaction on average (3.9). Irrigators of this zone evaluated the system with the highest level - compared to the other zones - specifically for the group of indicators Source of Water, which was pointed by farmers from Betmera as the more important issue for irrigated agriculture in the zone. Indeed, these farmers evaluated above others both the indicators Quantity (0.9) and Quality (5.0). However, the assessment performed for the Quality of the water is near the average value given by all farmers from Betmera (4.5), which means that there are no major differences concerning the quality of the water between this group and the others. On the other hand, Quantity was assessed by tail-enders 3.9 points above the lowest evaluation, done by their neighbors: irrigators from the left bank. Even though the evaluation of the Quantity done by the whole community was near the midpoint of the rule (0.0), hinting to be one of the most important and sensible issues at all schemes, pocket B, which has lined canals to convey water, achieved the highest evaluation (0.9). This indicator is directly linked to the assessment of Adequacy (1.2), sensibly above their neighbors of the A pocket (0.00), who irrigate through earthen canals. Furthermore, this difference of infrastructures seems to have an impact too on other indicators, improving the Tractability of the system too (5.2 in this zone, the highest among all zones) and facilitating the Operation & maintenance of the infrastructures (6.2).

Another indicator that was better evaluated by tail-enders than any other group was Insects and pathogens (3.5). Further analyses into the different areas that compose the B zone reveal that the highest assessments of this indicator were done by farmers from the downstream part (Gera If – 4.7 – and Gera Masano – 7.0), which was the part that didn't get water access for irrigation this year. Anyhow, this result contrasts with the result obtained for the indicator Availability of inputs, the worse valuated (2.5) among the four areas considered. Other interesting fact to consider from the perspective of area criteria is the Accessibility of technical assistance, which reaches the highest evaluation for the zone B (4.3), being Mai Tebatu the second one (3.2). These two schemes are the two closest to the village of Betmera (ketena Adirbaate), which suggests that better accessibility to technical assistance is achieved by farmers with plots close to the village, where DAs work.

Pocket BL - Tail-enders of the Left Bank

Farmers from this area evaluated the system with the lowest mark (1.6), almost two points below the next group, A with 3.3. Given the current situation for this group of farmers, in which they had to look for an alternative water supply (they are not managed anymore by the WUA of Shanfa Geladis), they showed their concern about the amount of water that they have available for irrigation, which is reflected in the results of the poll. They had the lowest level of satisfaction for the Quantity of water (-3.0) among all groups, whereas the Quality of water is not a problem from their perspective (4.0). The insecurity that these farmers perceive towards water supply is reflected in other indicators such as Social Support (-4.0) which decreases as we go towards the downstream part of the whole scheme of Betmera as it is shown on Figure 16. Group Atmosphere (-0.5) was also assessed with the lowest value among all zones, which in this case correlates to the lack of attention from governmental institutions. Hence, this group of farmers were the most critical too with the technical assistance, both for the Accessibility (0.5) and Effectiveness (-0.5), being the only group that assessed this indicators negatively on average. Concerning the results obtained for agronomic performance indicators, irrigators from the left bank evaluated the Soil Structure and Fertility of the soil considerably below other groups, with 0.0 and -1.0 respectively.

Fig.15. Social Support per zone in Betmera



*A: Head-enders; B: Tail-enders; BL: Tail-enders of the left bank
C: Mai Tebatu
Source: Own elaboration

Pocket C - *Mai Tebatu*

The group of farmers interviewed from the WUA of Mai Tebatu had a level of satisfaction of 3.5, being the second group after A more satisfied. The main concern for these farmers according to the qualitative information collected was the Quantity of water, assessed with -1.0, the third indicator with the lowest value, after Fund Generation (-4.5) and Social Support (-3.6). Given the reduced size of this WUA, water management appears to be straight forward, attaining the highest level of satisfaction for the indicator Predictability (3.8). This simplicity on water distribution is backed by the level of satisfaction observed for Flexibility (3.1), the lowest in Betmera, which suggests that turns are allocated reliably and without major changes, possible given the reduced number of irrigators – 12 out of 20 members of the WUA this year.

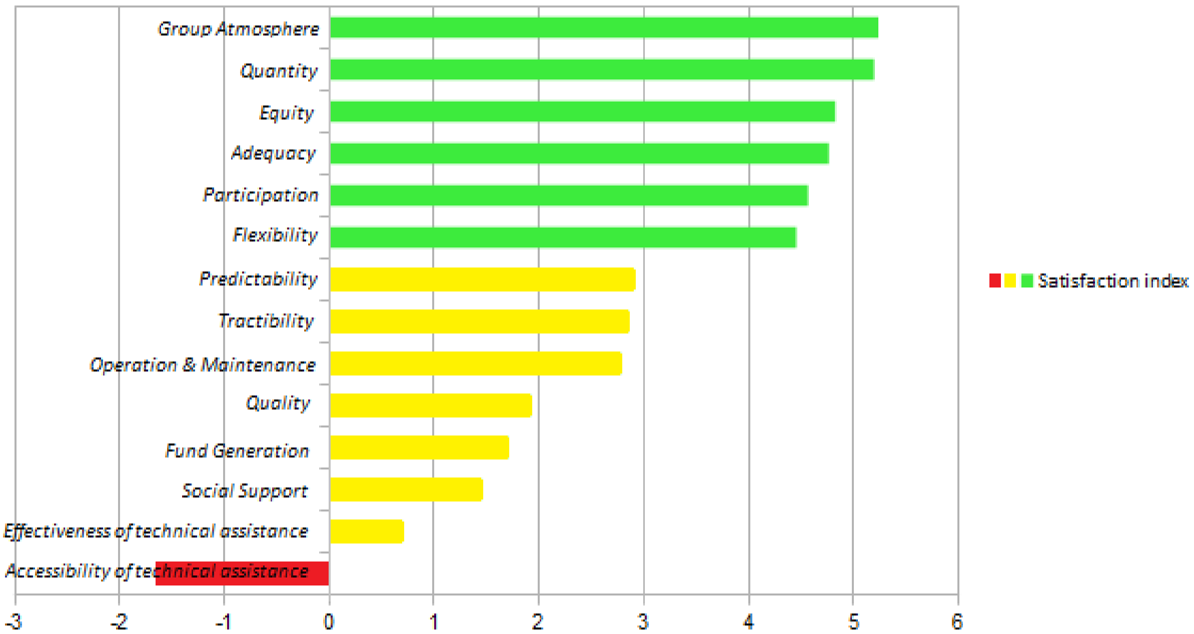
For the group of indicators of Group Dynamics the results were scattered in this WUA. Three indicators obtained a remarkable high assessment when compared to other groups – Participation (5.3), Group Atmosphere (6.2) and Operation and Maintenance (5.2) –, whereas the two others, Fund Generation and Social Support, got the lowest and second lowest evaluation (after the group BL), with -4.5 and -3.6 respectively. Concerning the economic capacity, they evaluated the system negatively since they don't have capacity to cope with the mentioned problems, having their only economic source through sanctions imposed to farmers. In what refers to the evaluation of agronomic performance's indicators, farmers from Mai Tebatu gave the highest value (5.5), revealing the strategic location of the scheme, protected from flash floods that happen at the watershed of the Zamra River, avoiding thus the problems of erosion that other farmers from Betmera actually face.

5.2.4.2. GUMSELASSA

In the case of Gumselassa the criteria that bring out significant differences for the levels of satisfaction were the 'zone', 'experience in agriculture' and 'educational level'. The result of the poll reveals that in general terms and for the indicators that have been used for this research, Gumselassa's farmers are satisfied with the performance of the irrigation scheme (3,2).However, the overall average shows that the degree of satisfaction can be defined as medium, and register considerable variations between groups of indicators such as between 'Financial resources & marketing' (4,4) and 'Technical assistance' (-0,5). This variance suggests that each indicator has to be looked in detail, considering the origin of the responses according to the classification of farmers described above. This allows extracting relevant results from farmers' evaluation of the scheme and be able therefore to analyze the perceptions that frame each assessment and determine the adequacy or not of the indicators used.

Concerning the Irrigation scheme level, six indicators obtained a positive evaluation, seven a medium (between zero and three) and just one indicator a negative one, the Accessibility of technical assistance, being graded with -1.7 on average by Gumselassa's farmers. Indicators of the group WQS had positive assessments for all of them, being Equity the best valued (4.8) and Tractability the worst (2.9). The group Source of water registered diverse evaluations for its two indicators, being the Quantity very positive (5.2) and the Quality medium, with an average level of satisfaction of 1.9. Even larger differences between indicators of the same group are found for Group Dynamics, for which Group Atmosphere got the highest assessment (5.2) and Social Support the lowest (1.4), with a difference between them of 3.8 points. The lowest evaluation was done for the technical assistance, being much lower for the Accessibility (1.7) than for the Effectiveness (0.7).

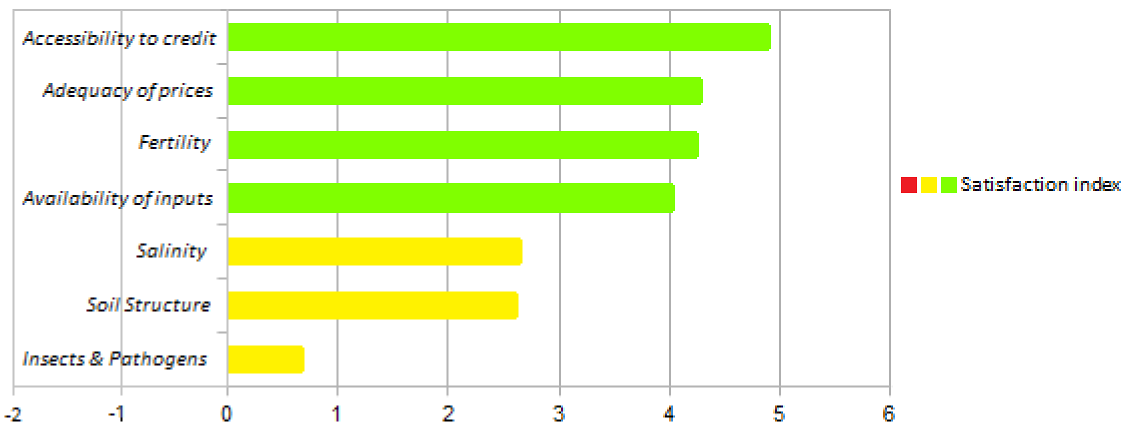
Fig.16. Levels of satisfaction at the Irrigation scheme level in Gumselassa



Source: Own elaboration

In what refers to the Farm level, economic performance indicators were very positively evaluated, registering assessments over four points (Accessibility to credit (4.9), Adequacy of prices (4.3) and Availability of inputs (4.0)). On the other hand, agronomic performance indicators got medium assessments except for Fertility (4.3). These values are dependent on the zone in which farmers work their plots, since there exists different concerns in different parts of the scheme, resulting in interesting information when looking at the indicators for each part.

Fig.17. Levels of satisfaction at Farm level in Gumselassa



Source: Own elaboration

- **Zone:** Among the seven groups of farmers considered by criteria of location of their plots, it can be observed that tail-enders show the more scattered results on average for all indicators. Those from the D/R part because they got the highest – on average – degree of satisfaction (4,2) and those from the D/L part for getting the lower (1,8). Being both positive, when compared to other areas they reveal interesting concepts for several indicators. Farmers from the seepage zone also got a high assessment (4.1), followed by U/L farmers with 3.8 and M/R with 3.4. Next group in the order of satisfaction would be U/R with 2.8 and finally M/L with 2.6.

- **Experience in agriculture:** This criterion has been divided into four subgroups: farmers with less than 15 years of experience, farmers between 15 and 30 years of experience, between 30 and 45 and those with more than 45 years of experience. Moreover, it has been included here a small reflection on the results obtained for the experience in irrigated agriculture, in order to complete the information analyzed and contrast the results from the statistical analysis.

Less than 15 years

This group of eleven interviewees provided the lowest value for the Quantity of water (3,7), which is remarkable given that along the other groups the assessment increases progressively towards the oldest group, being 5.1, 5.9 and 6,7 for 15-30 years, 30-45 years and more than 45 respectively. They were also the most critical with the Tractability of the system (1,2) and also unsatisfied with the Accessibility of technical assistance (-2,2), even though they provide the higher punctuation to its Effectiveness (2,6) compared to other groups more experienced and more critical in this sense.

Between 15 and 30 years

The only indicator at which this group provided the lowest value was the Accessibility of technical assistance (-2,4). Their evaluation was critically done through values close to their average, whereas the youngest and eldest groups tended to provide more extreme values.

Between 30 and 45 years

This group was the most satisfied with the Flexibility of the system (5,9) and more generally with the group of Water quality service (4,5). Concerning the Social support, they appeared to be one of the two most critical groups (0,6) together with the eldest (0,0). The lower level of satisfaction for this group was observed for the indicator of Insects & pathogens (-0,6) and compared to other groups of this classification, they ranked the first in the overall evaluation (3,7).

More than 45 years

The eldest group was specifically critic with the Water quality service (2,4), providing the lowest level for three out of the five indicators of the group (Adequacy (1,5), Predictability (0,5) and Flexibility (1,7)). They are highly satisfied (6,0) with the Availability of inputs and together with the previous group (5,4), the most satisfied with the Adequacy of prices at the market with 5.0.

Experience in irrigated agriculture

The results obtained for this two groups, divided into 'less than 15 years of experience' and 'more than 15 years', gathered similar evaluations in the general poll, 2.9 for the first group and 3.5 for the second one. Nevertheless, particularly relevant was the difference of assessments done by the first group on the Quality of the water (0.5), three points under the other group's evaluation. Other indicators of the poll were assessed more or less equally by both types of farmers, except the Accessibility of technical assistance, significantly lower for less experienced people (-3.2) than for the second group (1.7).

- **Indicators per zone:** Even though the statistical analysis didn't bring up as relevant this criterion, the diversity of perceptions and evaluations in the qualitative assessment make it essential to analyze as well the levels of satisfaction obtained per zone.

D/L - Downstream-Left

First, farmers from the D/L are the most critical with the Quantity of water stored at the source (3.7). In contrast, concerning the Quality (4.8) they appear to be more satisfied than any other group of farmers from other zones. Concerning the Water Quality Service, farmers of this area are, according to the results of the poll, more dissatisfied for the indicators of Predictability (0.2) and Tractability (0.2). Moreover, for three out of five of the indicators of Group Dynamics the lowest level of satisfaction was also registered at D/L farmers. Even though Participation (2.8) got a positive level, the reason of the lower degree compared to other zones might be caused by the fact that at this area many farmers abandoned their plots and are therefore alienated from Group Dynamics. Fund Generation (-0.6) and Social Support (-3.2) got the lowest mark among this group of farmers for this group of indicators.

In what refers to agronomic performance indicators: Quality of soils and Diseases, it is interesting to observe that these farmers perceive the Structure of their soils moderately (1.0) but not the lowest of the scheme, held by farmers of the middle part of the command area. Nevertheless, their perception towards Fertility (-1.5) and Salinity (-3.8) is negative and significantly lower than other farmers' perception about these indicators. Concerning Diseases, their assessment was positive for Insects & Pathogens (1.7), the highest among all areas. Finally, this group of farmers provided the lower degree of satisfaction also for the Accessibility of Technical Assistance (-3.6), which can be considered of particular importance for these farmers given the large number of constraints that they experienced to perform agricultural activities in this zone. All this factors made this group achieving the lowest degree of satisfaction of the irrigation scheme of Gumselassa.

D/R - Downstream-Right

As stated before, this group had the highest level of satisfaction compared to the other areas of the scheme. They gave the maximum level of satisfaction for the Quantity (7). In average, D/R farmers provided high levels of satisfaction for most of the indicators, leading the list for the groups of Source of Water (4.2), Water Quality Service (5.0), Quality of soils & Diseases (4.0) and Financial Resources & Marketing (5.7). Among the lowest indicators can be found the Accessibility of Technical Assistance (-1.5), which is the only indicator graded negatively. However, and in contrast to other zones of the scheme, they appeared to be satisfied with the Effectiveness of Technical Assistance (3.0) that for these farmers might have a key role in the satisfaction of their assessment of the performance of the irrigated system. Other relevant features of farmers from this area are those concerning information of the plots, being the average size (according to farmers' information) 0.19 ha, the lowest of the scheme and the average start of farming activities at their plots in Gumselassa the latest, in 1997. However, their experience in agriculture appeared to be in average the highest among all zones, with 32.7 years of experience.

M/L - Middle-Left

The degree of satisfaction of this group of farmers was the second lowest (2.6), followed closely by U/R farmers (2.8). Farmers with plots at this zone appeared to be dissatisfied with the Quality of water (0.2) for several reasons: the use of detergents, the saline nature of the water at the dam and the fact that animals also use the water, which brings sediments with it. Also remarkable is the fact that farmers from this area evaluated the Soil Structure of their plots with 0.5, which together with M/R farmers (0.8) form the lowest level of satisfaction for this indicator.

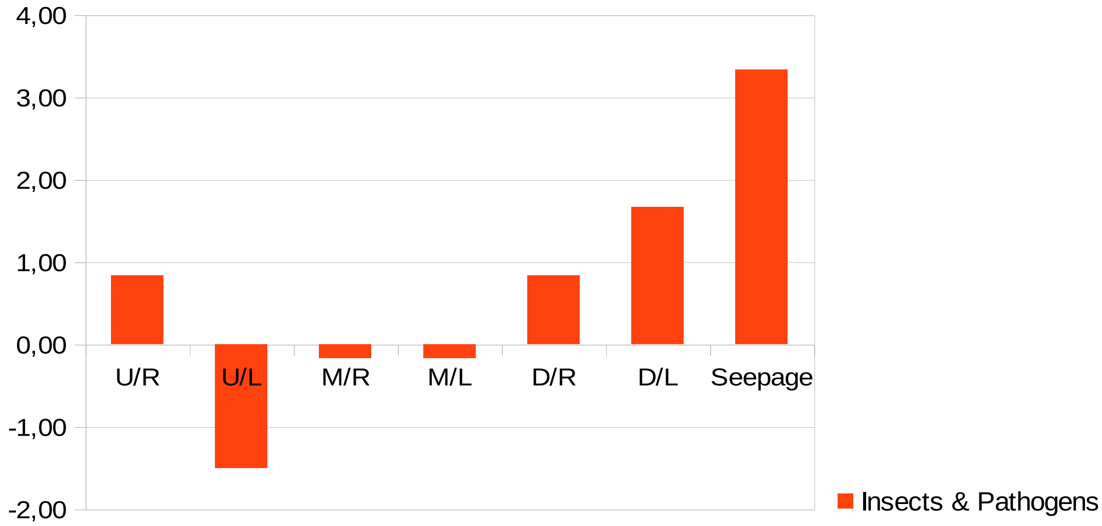
M/R - Middle-Right

Similarly to D/R farmers, M/R ones evaluated very positively the Quantity of water (6.2) stored at the dam. More remarkable is the fact that they evaluated the Equity of the system with the lower level (3.0), even though it is still positive and shows a medium-high level of satisfaction. On the other hand, they resulted to be the group of farmers with the best level of satisfaction for the Group Dynamics (4.5). Particularly noticeable were their levels of satisfaction, compared to other zones of the scheme, respecting Participation (5.6) and Operation & Maintenance (5.0). As described before, plots of the middle part seem to gather the lowest degree of satisfaction from farmers' perspective on the Structure of the soil, having both areas similar assessments on Fertility and Salinity too. Finally, their satisfaction on the Effectiveness of technical assistance (0.0) was among the worst, which could be caused by the high experience in agriculture of the interviewees.

U/L - Upstream-Left

Comparing data of this area to neighboring zones (U/R and M/L) similar levels of satisfaction can be observed for indicators of Source of water and Water quality service. Nonetheless, some relevant results were gathered among farmers of this zone for Water quality service's indicators. Thus, they were the group of farmers more satisfied with the Predictability of the system (3.8). Also relevant is the low satisfaction showed about the Tractability (1.2), contrarily to the regular high satisfaction showed by head-enders. Concerning agronomic indicators, farmers of the U/L part were the group most satisfied with the Quality of their soils, either for Soil structure (5.3), Fertility (6.3) or Salinity (5.5). On the other hand there is a high prevalence of Diseases in the area, which was assessed by this farmers with the lowest level (-1.5) among all the command area.

Fig.18. Levels of satisfaction for the prevalence of Insects & Pathogens per zone in Gumselassa



*U/R: Upstream Right; U/L: Upstream Left; M/R: Middle Right
M/L: Middle Left; D/R: Downstream Right: D/L: Downstream Left
Source: Own elaboration

U/R - Upstream-Right

Farmers of the U/R part are the most dissatisfied with the Source of water's group of indicators. Even though they assessed positively the Quantity (4.2) they gave the lowest punctuation after D/L farmers (3.7). Thus, U/R farmers evaluated negatively the Quality of the water (-1.7). Also remarkable was the evaluation done by these farmers over the Operation & maintenance of the network (1.0), which was the lowest among the members of the WUA. Furthermore, they were the most critical group with the Availability of effective inputs (1.5), arguing that they are expensive and that other effective inputs different than fertilizers are difficult to get, which was linked by them to the lack of suitable chemical products to solve their problems with Insects and pathogens (0.8), also remarkable in this zone.

Seepage

Given the reduced number of farmers using water from the seepage interviewed so far, few conclusions can be made to describe the assessment of these farmers over irrigation performance. However, some results indicate the main problems that these people face in irrigated agriculture. For instance, they appeared to have specific problems on the Operation & maintenance of the network (-2.0), which in comparison to the perception of farmers from Gumselassa (3.3) seems to be a major constraint for the normal development of agriculture. Other indicator relevant in comparison with other groups would be the Accessibility to credit, assessed with 1.7 in this though, and even though it's positive, it is 2.5 points away from the next group, D/L. However, the analysis of this group of farmers is complex given the different types of irrigated agricultures performed here (pumping water from the seepage, use of collective wells, etc.), reason why the comparison with farmers from the WUA of Gumselassa requires further research and careful analysis.

CHAPTER VI. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1. DISCUSSION

In this chapter the results of the study are discussed in relation to the methodology proposed, the quality of the data collected and the specific results obtained. Furthermore, the conclusions derived from the study are presented together with a set of recommendations aiming to improve further researches on the topic.

6.1.1. METHODOLOGICAL CONSIDERATIONS

In general terms and based on the results obtained, it can be stated that the methodology used comes up with a reliable process of evaluation of irrigation systems done by farmers. Firstly, the grid of indicators purposed covers efficiently the technical, social and economic dimension of irrigation systems, being classified according to the system domains defined by Small and Svendsen (1992), further developed by Gorantiwar and Smout (2005) and Bos et al (2005). This frame where indicators are classed allows for a straight-forward assessment of IS by farmers. Secondly, the approach proposed for the poll of a joint qualitative and quantitative evaluation, in which farmers are asked about the main problems related to each indicator and the most suitable solution is useful to identify farmers' constraints at different levels and their adaptations to the system. Through this approach, acknowledge by authors like Rao & Woolcock (2003) and Chaponniere (2012), it has been possible to develop a record of farmers' technical innovations and adaptations, one of the objectives of the research and an important means to improve IS performances based on farmers' point of view. Thirdly, the combination of the opinion poll with the complementary questionnaire enables to identify farmers' point of view accurately, which can be used to develop a typology of farmers at the study sites that facilitates the comprehension of farmers' perception in the assessment of each indicator. Finally, it has shown coherent results that match with the diagnostic performed by technical experts, contributing as well to identify new paths that lead to improve IS in all dimensions.

On the other hand, some other aspects didn't satisfy the expectations created. For instance, the identification of the interactions among actors involved in irrigation processes was not fully covered by the methodology proposed, given time constraints and contradictory farmers' perception in this sense. Nevertheless, it was completed with the parallel study undertaken, which analyzed the institutional arrangements of IS and was therefore complementary to characterize the mentioned interactions, contributing to build farmers' perception. Another point that didn't fulfill the expectations was the objective to get feedback from farmers after each interview. In this sense, farmers showed a lack of criticism or ideas about the method when asked about it, which could be due to an improper approach of the question, leaving room for its improvement in further researches.

All in all, this methodology serves as a useful tool in order to collect real farmers' opinions about the performance of irrigation systems. The fundamental difference with other approaches based on quantitative data collection and technical assessments is that farmers have, individually and anonymously, the opportunity to express their point of view about IS's performance in the social, technical and economic dimension. This allows for a better characterization of the problems and solutions needed to be implemented, given that each farmer has an opportunity to reflect about the IS from his single point of view instead of relying on the only assessment of rural leaders. Thus, when compared to other participatory approaches framed in the Project EAU4Food such as Communities of Practice (CoP) and Learning Practice Alliances (LPA), this methodology gives to farmers the central role. By the method proposed, farmers are the key actor of the evaluation, being included along the whole participatory process in different ways: firstly by participating in the selection of indicators of the grid; secondly by providing feedback about the methodology at each interview and finally by participating actively at a group meeting where they discuss about the main problems identified, as well as the solutions provided by them in order to improve the performance of the scheme. Nevertheless, this methodology presents several opportunities of improvement, starting by a better survey's design to collect farmers' feedback about the method as stated above. Besides, turning the sampling method into a census would allow for a larger data collection, higher representativeness of the results and deeper understanding of farmers' perception towards IS. This would require the participation of several surveyors, which would also leave time to characterize better other actors involved in irrigation processes. Taking into account these aspects, it is possible to develop a new procedure that can be useful to achieve an effective assessment of performance of irrigation systems.

6.1.2. QUALITY OF COLLECTED DATA

Concerning the quality of the data collected, it is essential to remark first of all the importance of a clear communication between farmers and researchers. In this sense, the role of translators has key relevance in order to achieve significant information, which can be used to extract general and particular conclusions out of the study. This research had up to four translators at both study sites, being the results collected only with two of them included in the analysis, given the problems experienced with the two others. Nevertheless, the quality of the interviews performed with the two official translators was optimal, even though the time required transferring accurately qualitative information both to Tigrinya and English, which also was a major constraint at the meetings organized. Other constraints related with the time used at the survey were the time necessary to explain the poll. Despite the fact that the ruler was conceived to be able to be answered by illiterate farmers, some of the interviewees have troubles in understanding the principle and some others directly didn't want to undertake the poll. This could be due to a deficient explanation from the translator or to some farmers' incapability to understand the ruler, reason why the explanation of its operation needs further development in order to be easily understood by all farmers.

In what refers to the survey, some adaptations had to be done during the fieldwork in order to optimize time and make the interview logical and coherent to each topic. Thus, questions related to External factors (Financial resources & Marketing), had to be changed of the pre-established order, putting them before the indicator related to each topic. Thereby the structure of the interview became more consistent, reducing too the length of the introductory questions complementary to the poll. Specifically for the opinion poll, it can be generally stated that the answers provided by farmers correlate with the reality of the irrigation schemes of both study sites, what proves the success of the method used to assess IS. However, even though the results of the indicators are coherent among them, the values obtained are notably high compared to the problems observed and commented by farmers, which is one of the major weaknesses of the research, preventing from extracting relevant conclusions in determined dimensions. Moreover, farmers tend to give the extreme punctuation to positive assessments more often than for negative ones, which resulted in a general homogeneity of results that tended to high positive values. Even if farmers orally state that a determined indicator is performing very deficiently, they hesitate to assess it with an extremely low evaluation, what doesn't correlate with the qualitative assessment. Hence, negative assessments are hardly achievable on average, which causes delusory results when compared to the real performance of the schemes. However, this may differ from one type of farmer to another, what will be analyzed in the next section of this chapter. Also concerning the results obtained for the poll is essential to discuss the representativeness of the research, which was similar for both study sites. The number of farmers included in the poll was 39 at each study site. Given the number of plots cultivated this year at Gumselassa (202) and Betmera (around 150), it can be stated that the representativeness of the study is low, since it didn't reach a significant number of farmers. A higher number of farmers sampled would have allowed drawing validated conclusions and completing information about farmers' problems and solutions adopted. However, the sampled method used, a random stratified sampling, provides precise information since no farmers' population has been excluded, considering beforehand all farmers' type existing in both study sites. This sampling method has been performed within the zones determined for each study area, improving the representativeness of the sample by reducing sampling error and allowing for an accurate analysis of the results performed for each type of farmer.

Particularly for the grid of indicators selected, it was designed to cover the social, technical and economic dimensions as it was said before, even though these dimensions are not equally covered in it. This is mainly because of the context-adapted nature of the methodology, which framed in the EAU4Food project aimed to target the problems already identified by researchers and further enriched the grid with farmers' feedback, trying to obtain useful information about the key issues of the IS. Thus, given the observed problems of water management in Gumselassa, this methodology is mainly focused on water management and social indicators that concern WUAs. These include 14 out of the 21 indicators including those related with technical assistance, even though some such as Fund Generation are also linked to the economic dimension of irrigation. Among the others indicators, four of them concern the technical-agronomic dimension and the remaining three the economic one. In this sense, there is a lack of knowledge about household incomes and remunerated activities that made difficult to determine beforehand the adequate indicators that target their needs and problems. Thus, the indicator related with credit opportunities for instance should have been reformulated and analyzed more deeply, which could have helped to collect better data, more adapted to farmers real problems related to credit facilities. Nevertheless, the need to develop accurate explanations of each indicator, easily understandable by every farmer, is plausible. For instance, many farmers understood the indicator Predictability as Timeliness or Reliability, which could be caused by the fact that these are more important for them in comparison to Predictability or because the indicator was not clearly formulated. It can be therefore stated that a clear formulation of the indicators, assimilable by farmers, is essential for a successful development of the opinion poll.

Despite the fact that the methodology is done to comprise most of farmers and their concerns, it seems logical that farmers that suffer for instance problems of salinity are not equally interested and conscious about Group Dynamics' indicators. Based on the field experience, this fact suggests that the poll should be done with certain flexibility in the order of the questions. In order to improve the poll, there is a need to adapt some order of questions when it is known the main concern of the farmer i.e.: salinity. Similarly, the indicator Accessibility of technical assistance preceded the Effectiveness of technical assistance, given that farmers used to prioritize the latter from their perception. Farmers regularly pass by indicators that may not interest them that much and want to explain directly their main concerns. Sometimes changing the order of indicators like salinity-soil structure allows for a more logical explanation of soil structure. In short, it is recommendable to go first to the core of the problem so that later it can be further divided and analyzed into different indicators, such as salinity first, in order to break down better farmers' opinions about soil structure or adequacy. Being the mentioned flexibility subject to different perceptions, it can be generally applied to both study sites, which present common characteristics that need to be taken into account beyond the interview strategy.

Finally, it is important to remark the role of key actors of IS when the data collection is performed. At the village of Betmera, leaders as the Tabia manager and abo-mais persuaded the translators to avoid translating literally what farmers said, specifically when they criticize the IS or complain about the social management of the irrigation schemes and the village organization itself. Fortunately, this didn't interfere directly in the research since the translators communicated this problem and translated efficiently what farmers had to say. However, it is overt the influence and pressure that leaders can make on farmers when making the interviews, even though it was always clearly stated the anonymous condition of the interview. Farmers, often screened out of the evaluation, actually have strong opinions about crucial issues of the scheme. The problem of leaders' influence though could be reflected in the relation between the level of satisfaction registered and their actual opinion collected through semi-structured interviews in the form of qualitative information. As stated above, farmers tend to give positive assessments in the ruler even though through their speeches they are dissatisfied, which was specifically problematic at Betmera because of the pressure of rural local leaders.

6.1.3. SYNTHESIS OF THE DIAGNOSTIC

In this section are analyzed the results obtained for the survey and particularly from the opinion poll. The main ideas about which farmers showed their satisfaction or dissatisfaction are therefore dissected, analyzing what differences of perceptions lay behind the different categories of farmers considered and what opportunities offer the innovations suggested by farmers in order to cope with the problems identified.

Beyond the application of a new methodology in the field, the comparison of a traditional irrigation scheme with a newly implemented irrigation project like Gumselassa revealed interesting results related to farmers' different perceptions at both schemes. These have evident impact on the performance of the IS, shaping farmers' vision of the problems, their adaptations to and also their assessment of it. However, farmers of both sites share a common politic and economic context, which has marked the trajectory of agriculture and serves as starting point of this synthesis. A common aspect between farmers from both sites, influenced by the political context, is the fact that they have to buy fertilizers mandatorily in order to have water access. Being both study sites located in a drought prone region, farmers of both sites complained about the fact that using fertilizers with low doses of water could affect seriously the growth of their crops. Nevertheless, strong policies aiming to boost a green revolution force these farmers by threatening them by both being excluded from the Safety Net or not having access to water, which is responsibility of each WUA, following guidelines of the Tabia or Woreda administration. This imposition heavily conditions farmers' activities in the technical and economic dimensions. Firstly, because they can have a counterproductive effect, risking the growth of the crops and secondly because of the vicious cycle in which most farmers are involved, asking for credits to pay the inputs, which cost is hardly covered by their harvest, given the low productivities achieved, related to problems of water availability, salinity or agricultural practices.

Looking at the criteria considered in this research, many other conclusions can be drawn commonly for both schemes according to the results obtained. Firstly, comparing the results from the survey and the poll, it can be stated that even though there exist similar farming typologies, there are significant differences of perception beyond the commercialization of the products or type of production that influence directly in farmers' assessments. For instance, concerning the results obtained for the criteria 'experience in agriculture', it can be observed that even though both groups evaluated positively the IS, the difference of assessments suggests that experienced farmers on irrigation may achieve higher performances and therefore be more satisfied with the system as a whole. This corresponds with farmers' opinions gathered through qualitative information, where inexperienced farmers complained about the situation of technical assistance for irrigated agriculture, detailing the number of problems that they face and don't know how to deal with. On the other hand, most of experienced farmers assisted to training courses when the dam was built in the case of Gumselassa and around that date too in Betmera, making a relevant difference with newcomers in terms of irrigation management and technical issues. In what refers to the level of education, it can be highlighted the role that religious actors play in IS. Given that many of the interviewees that had a religious education were priests, it is necessary to take into account the special status that religious actors have at the local level for the community. Thus, some priests have close relationships with water managers, having occasionally better access to water, specifically in the schemes of Shanfa Geladis and Mai Tebatu. This situation is reflected in the high satisfaction showed at the poll by farmers with religious education for indicators related with water distribution and economic performance, as well as in the qualitative information collected with some priests, who assured to receive water turns more often than other farmers.

Analyzing each indicator for both schemes, the results obtained at the poll reflect the difference between both schemes concerning several indicators. For the source of water, the irrigation schemes of Betmera obtain water from a system of diversions, with little storage capacity, while farmers from Gumselassa profit from an earthen dam that supplies water to farmers reliably and regularly for irrigation, which was manifest in the higher assessment of the quantity at Gumselassa. Concerning the quality, even though the assessment at both sites was positive, it demonstrates farmers' concern in Gumselassa about the fact that people wash their clothes at the upper part of the scheme, perceiving it as a risk for the growth of their crops. In contrast, in Betmera they consider that the water, coming from the source of Faleg-mai, has an excellent quality, only partly polluted when flash floods occur, carrying garbage and sediments in the water. For the group Water Quality Service, fundamental differences in water management are attested in the poll. In what refers to the Adequacy, differences in assessment may be due to the fact that farmers from Gumselassa profit from unlimited time to irrigate their crops, having access to water until the moment they consider it is enough to cover their CWR. On the other hand, farmers from Betmera have water turns of six hours, which according to their perception and the results of the poll is insufficient to cover their water needs. Furthermore, the assessment for the Predictability changes substantially due to the diverse approaches. At the IS of Gumselassa farmers need to assist at the mornings to get water turns, which is not assured just by their assistance, while in Betmera turns are decided on a weekly basis on Sundays. From the interviews it can be stated that farmers claim for a register of the turns and for an alternative distribution of turns that doesn't require them to go that often to the WUA meetings. Finally, Flexibility also reflects at the poll the different management system between both schemes, given that it depends on managers' criteria in Gumselassa and on community's decision in Betmera.

For the group of indicators Group Dynamics, two indicators have specific relevance when compared to the others according to the results obtained. Firstly, Social support, which was negatively evaluated in Betmera given the fact that last institutional support, through the construction of hydraulic infrastructures, was provided by the CoSAERT around ten years ago. From that date, only expired cement has been provided to farmers with the aim of supporting them to build lined canals and night storages. In contrast, farmers from Gumselassa had a better assessment, which comes mainly from the fact that they have support from researchers of Mekele University, rather than direct support from the Woreda or Tabia administrations, only providing "deficient" technical support, according to farmers' perception. Secondly, Operation & maintenance, that showed a remarkable diverse evaluation of the system. This can be due to the different feelings of community existent in both schemes: Betmera is a community with large experience in irrigation, where the plots are located at a short distance from their households, whereas Gumselassa is a new irrigation scheme, in which farmers from scattered villages own different plots. This may influence on farmers perception, creating a sense of ownership towards the IS that influence in its operation and maintenance, reason why in Betmera they have a better assessment of it. In Gumselassa, this situation changes completely, which is reflected in serious problems of maintenance of the canals and conflicts between head-enders and tail-enders associated to it. Indicators of Agronomic performance also had relevant differences in the evaluation, notably Salinity and Insects & pathogens. For the former, it comes from the fact that there are no major problems of Salinity in Betmera, while in Gumselassa is one of the main issues to be solved. For the latter, it could be due to the minor incidence of mono-cropping in Betmera, being a major constraint for agriculture in Gumselassa. Concerning the economic dimension, the most significant difference was given for the Adequacy of prices. In this sense, the existence of Adigudem's market seem to have a strong influence with higher prices than the villages of the Tabia of Betmera, worst communicated and less populated than villages of the plain, where market activities are experiencing a rapid growth. The last two indicators, related to the Technical assistance, also revealed a remarkable difference, in which farmers from Gumselassa where much more dissatisfied than farmers from the mountains. These two indicators point out a significant problem of technical assistance in Gumselassa, where the DAs are, according to farmers' perception, unable to solve the current problems that farmers face related with water management and agriculture. According to the qualitative information obtained through the interviews with DAs and the Office of Agriculture and Natural Resources, this issue has its roots in the fact that DAs are responsible of diverse areas – preventing them from providing specific and adequate advice to the farmers – and in their deficient technical background.

Betmera

The irrigation schemes of Betmera, as stated above, are worked by farmers with a strong sense of ownership. Even though the number of owners interviewed is similar for both study sites, it can be stated that more owners most of the owners of the plots (except those too old to work) work actively at the field, helped by family members or neighbors, with a reduced number of sharecroppers hired to work. Thus it was observed that a larger number of women work their plots – particularly in the scheme of *Mai Tebatu* – whereas in Gumselassa a reduced number of women do. Furthermore, *Mai Tebatu* registers the lowest level of education among all the study zones considered. Both facts – sense of ownership and level of education – contribute to build farmers perception, influencing on farmers' agricultural practices. However physical constraints also shape farmers' decision, as for instance water availability or the type of crop, which influence on irrigation practices. Hence, some farmers irrigate by flooding if there is enough water and by furrows when water is scarce. In this sense, farmers irrigating by furrows did lower evaluations of most of the indicators, specifically those concerning water management, prompting the fact that from farmers perception water may be scarce for their crops when they don't irrigate by flooding, as they used to do traditionally.

Looking at each indicator interesting facts are found per each zone. For the upper part of the WUA of *Shanfa Geladis* some indicators have specific relevance. The results for Tractability reflect the physical situation of water distribution, the different assessment for the lined canals of the B zone and the earthen canals of A, which difficult water conveyance to the plots according to farmers' perception. Flexibility, unlike Tractability, is directly linked to the management of water distribution. In this case, this significant difference may be linked to the fact that the three water managers of the whole WUA (A and B) own plots at the A (head-enders) zone. Thus, even though the rules of the WUA set that in order to provide extra turns they have to be first validated by the whole community, some farmers pointed out that flexibility may not be equal for all farmers, suggesting that there exist 'informal flexibility' among the neighbors of water management. A remarkable different evaluation between A and B was also done for Availability of inputs. This difference could reveal better access to pesticides, blocked by honeybee producers, and/or a better organization towards inputs acquisition, given that they need to form groups of four or five farmers in order to purchase these inputs. Indeed, farmers normally need to discuss with honey producers about the possibility of using the inputs, which can be achieved easily through the support of relevant actors of agricultural production in Betmera, such as the water managers or *abo-mais*. Concerning the Adequacy of prices, it was observed that farmers that practice subsistence agriculture perceive that crop prices are good enough even though they prefer to keep it to feed the household. Hence, it can be stated that they assess the indicator as a client. In contrast, farmers that actually sell their crops complain about the difficulties to cover their production costs, showing deeper knowledge about the marketing characteristics and assessing the system in this sense as a producer.

For the zone B, Quantity had a very positive assessment when compared to other zones. This fact is likely to be linked to the fact that in the B zone canals are lined, optimizing water management and minimizing water losses according to farmers' perspective. The indicator Insects & pathogens was also better evaluated here. The fact that the plots worked by these farmers are better assessed can be attributed to the real absence or lower incidence of insects and pathogens, given the reduced number of plots currently cultivated in this area. However, it can also be determined by farmers' perception towards the evaluation, who often only consider the current season when they perform the assessment of the scheme. For the Availability of inputs, given that this indicator covers not only chemical inputs, but also fertilizers and improved seed varieties, the diverse assessment between both areas can be linked to the previously mentioned estrangement of farmers from this area with water managers. In what refers to the Technical assistance, schemes close to the village had better assessments than those that are further. This could imply that farmers' complaints about the reduced availability of DAs to visit the plots is certain, needing to go to the village to ask their doubts to the DAs instead of having technical assistance directly at the field. The community of irrigators of the left bank had remarkable results for the indicators Social support and Group atmosphere in comparison to other zones. After their exclusion from the WUA of Shanfa Geladis farmers feel unprotected against potential droughts and perceive that the future of irrigated agriculture as precarious, which would lead them to food insecurity for coming years. This division brought mistrust from farmers towards governmental institutions, specifically the Tabia administration, which didn't provide any support or compensation to these farmers in order to cope with water scarcity. Moreover, this scarcity resulted in a reduced water use for irrigation and numerous complaints about the management from those who profit from water turns, pointing out irregular practices and impossibility to implement economic sanctions, due to the extreme poverty of these farmers. Concerning the Soil structure and fertility they had medium values at the ruler, but much lower than other zones of the IS. Yhis is due to the fact that the plots located at the left bank are particularly exposed to flash floods' erosion, which in agricultural terms is translated into the removal of valuable topsoil and loss of organic matter, which can change and weaken the structure and even texture of the soil, affecting its water-holding capacity and making it even more sensible to water scarcity.

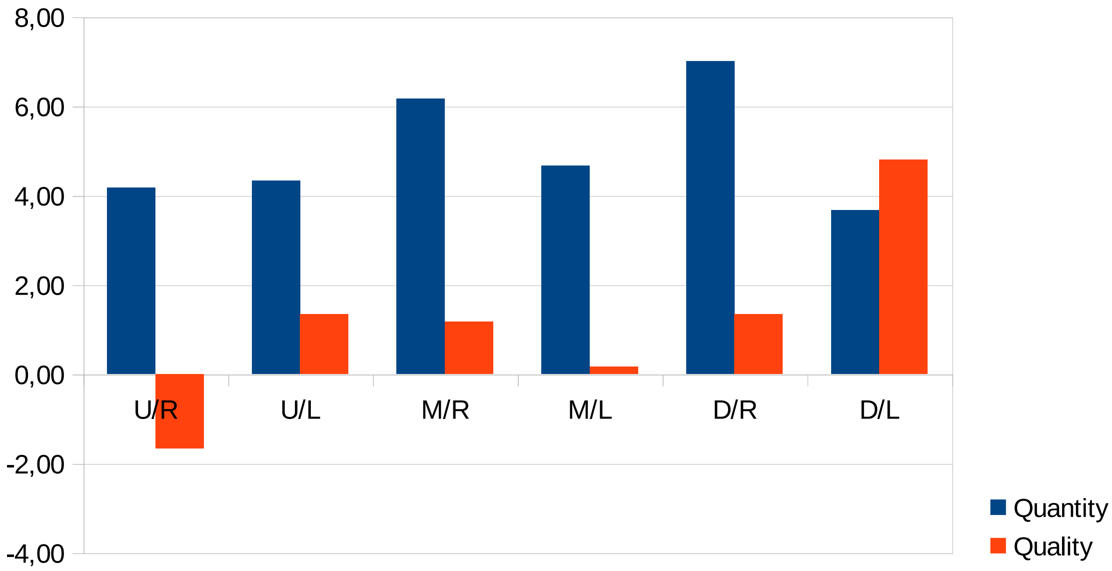
Farmers from the zone C were after A the most satisfied group. This group has particularly problems related to the indicator Quantity. Thus, farmers stated that with the traditional infrastructures to collect water they experienced high losses. They added that the size of the dam is not big enough to collect water to irrigate all the plots of the zone, reason why they believe the quantity of water stored is insufficient for the effective irrigation of all plots. Particularly interesting for this group was the group of indicators Group dynamics. The three first indicators were near the maximum level of satisfaction, revealing the active implication of these farmers in irrigated agriculture and highlighting their commitment in achieving optimal results through collective management. However, this association is not recognized by the local administration, which is reflected in their opinion about the social support received. In this sense, farmers complained about the lack of support when building their infrastructures after floods occur, with a considerable impact in terms of time labor and money according to them.

Gumselassa

Several indicators can be discussed based on the relevancy of the statistical results of this scheme, contributing to identify farmers' perception by zone of the performance of the scheme. Downstream-Left farmers had a low assessment of the Quantity, which could be associated to the problems that they experienced to receive water. For the whole group Source of water farmers of this zone had a higher assessment, which can be attributed to the fact that upstream farmers, given probably to the proximity of their plots to the dam, are more concerned about different aspects of the Source of water, quality in this case, than tail-enders. Predictability and Tractability are also problematic aspects for these farmers: both relate to the difficult conveyance of the canals associated with the 'deficient design' of the network, which doesn't cover the command area foreseen. It seems therefore logical that farmers from this part graded these two indicators with levels sensibly lower than other areas of the scheme. Farmers from D/L are somehow alienated from the WUA's group dynamics and the irrigation scheme activities. They don't have a reliable source of water but big problems of erosion, soil structure (waterlogging) and salinity. They often do not have any opinion about numerous indicators and many of them are thinking on transferring the plot or are already farming another plot somewhere else.

All six farmers interviewed from the D/R part, rather than complaining about their tail-enders' condition and a hypothetical difficult access to water, they appeared to be fully satisfied with the quantity of water at the dam. As it happens with D/L farmers with the issue of Quality, D/R farmers don't seem to be concerned at all about the problems of siltation of the dam commented by head-enders, reason why they had the maximum level of satisfaction for the quantity. Hence, as it can be seen in Figure 20, the assessment of the Quality increases as we go upstream, which also occurs for the Quantity with the exception of D/L farmers, who have problems of water conveyance that can be linked to this evaluation. It can be therefore assumed that the location of the plot plays an important role on farmers' perception.

Fig.19. Assessment of the Source of Water per zone in Gumselassa



*U/R: Upstream Right; U/L: Upstream Left; M/R: Middle Right
M/L: Middle Left; D/R: Downstream Right: D/L: Downstream Left
Source: Own elaboration

Unlike U/L farmers, M/R farmers experienced some problems of Equity and Predictability reflected in the results. One possible cause is that at this part of the scheme are concentrated numerous plots that are currently cultivated, therefore are more likely to experience concurrence in water demand and conflicts around water too. Plots of the middle part had significant assessments for the Insects & pathogens, negative for U/L, M/L and M/R. This fact could be influenced by the lack of fallowing in the rotation of their crops enhanced by the high density of plantation and the reduced diversity of varieties planted in this area. Thus, the prevalence of insects and pathogens can be higher in this zone than in others of the scheme. Finally, upstream farmers complained systematically about the lack of commitment showed by downstream farmers for the maintenance of the system, given that in their opinion tail-enders are not involved in the canal cleaning programs. It can be stated then that farmers have a geographically limited scope of the scheme, since at each zone farmers have different concerns and therefore different assessments of the system.

Concerning the results related to the innovations, there's a lack of support to innovative farmers that innovate by self-initiative, who complain about the fact of not being included in farmers' training programs. It can be therefore stated that innovative thinking is not really encouraged by the administration. Instead, farmer training programs are creating a farmer' elite (leaders of WUC, gujiles, etc.) alienated from real farmers' problems and without critical spirit, which makes innovations difficult to appear. It is necessary to involve those farmers in the training programs, with the objective of enriching agricultural knowledge through alternative thinking. By creating associations of innovators as it happens in Betmera for several farmers, it would be possible to scale-up key innovations to other irrigation schemes, facilitating exchange between different communities through group meetings and field visits. By doing so, key innovations like cooperative commercialization, use of compost, organic pesticides like 'chergued' or use of urea could be scaled-up geographically.

6.2. CONCLUSIONS

The traditional paradigm of evaluation of irrigation systems has given more weight to technical experience or economic profitability criteria, with the goal of fostering local development. Thus, small farmers have been typically forgotten not only when IS are evaluated but also when important decisions concerning agricultural management are taken, as for the case concerning the use of fertilizers. Hence, in order to change the paradigm, it is necessary to reconsider the role of all actors at different dimensions – technical, social, economic and environmental – specifically for the users of the system. In this revision of actors' roles, another terminology should be assigned for the so called small farmers/smallholders, concepts based on their economic performance and physical land occupation. Familiar agriculture would be a more appropriate idea, more adjusted to the social role played by these farmers and essential for the good performance of IS. So, to understand their concerns and ideas on the three dimensions of performance of irrigated agriculture, this research develops a methodology that aims to collect efficiently farmers' opinions and assessments of two irrigation schemes in Ethiopia. The conclusions derived from the study are summarized as follows.

- *Does the methodology provide an effective means to collect farmers' point of view concerning IS? Is it possible to apply it efficiently to other irrigation schemes?*

The methodology is developed aiming to assess in a generic way different IS. Its application at the field was positive since it resulted in validated information about both study sites as detailed in the results. However, it is essential to conceive the method as a flexible approach in which farmers need to be involved at all stages of the methodology: design, implementation and treatment of results. By doing so, it is possible to develop a coherent approach that is context-specific and susceptible to be extrapolated to other sites. Nevertheless, it is crucial to keep the balance between the different dimensions of irrigated agriculture, given that a diversified grid of indicators enriches the assessment. This allows setting links between different indicators and dimensions, contributing to identify and clarify the causes of the problems and the potential solutions that could effectively be implemented to cope with them.

- *What methodological paths should be followed to improve the current method?*

In order to ameliorate the methodology proposed, several considerations need to be taken into account based on the field implementation. Firstly, it is needed a clearer conception of the approach to include farmers' opinion during the implementation of the methodology. Developing easier ways to get feedback is critical to improve the evaluation and to include their view about all factors that can influence on the performance of IS. Secondly, it is important to analyze in depth contradictions between quantitative and qualitative information provided by farmers. This may lead to a re-conception of determined indicators that can bring farmers to uncomfortable feelings when answering to the poll, as it happened with the indicator Equity. Furthermore, it offers the opportunity to research how farmers link indicators among them in their answers, given that very often they explain issues related to other indicators, facilitating thus researchers' understanding of their points of view and clarifying possible contradictions.

- *How does farmers' perception influence in the conception of the poll and its implementation?*

Farmers' perception towards irrigated agriculture is shaped by their experience in the field as clients and producers. This duality of farmers represents an opportunity for researchers since they can provide multiple perspectives in the socio-economic and technical dimensions. On the one hand, they provide a different perspective in the stage of conception compared to researchers and donors, which is linked to specific problems of water management and agricultural production often not visible from outsiders. On the other hand, at the evaluation farmers perceive indicators in a different way as researchers do. As stated above, they frequently link facts that combine different indicators in their qualitative assessment, which provides useful information about the general performance as well as it shows new ways of conceiving indicators for further researches.

- *What limitations and opportunities enclose local innovations for attaining positive change in both irrigation schemes? How can it be done?*

Attaining positive change requires a proper characterization of the innovations, their constraints and opportunities. The present study sets a platform where a set of innovations conceived to cope with specific problems are identified, offering the possibility to scale up these innovations to schemes of similar characteristics. The innovations identified by farmers present a multi-dimensional character, offering alternatives in the social, technical and economic areas. Thus, among the innovations proposed by farmers – exposed in the results of this research – several are susceptible of being scaled-up at a Regional level such as the use of 'chergued', SWC techniques to tackle waterlogging and salinity, marketing strategies or joint evaluations of IS between farmers and Woreda's experts. However, it is needed that governmental bodies change their strategy concerning farmers' training, given that it is regarded by innovative farmers as a blockage to alternative practices, enforcing a top-down technical approach not adapted to farmers' needs. In this sense technical assistance plays a key role in the adoption of solutions to the existing problems, having the required background and knowledge to give accurate advice on agricultural practices. It seems essential then that a common platform aiming to develop further farmers' innovations is implemented, gathering the institutional support provided in FTC, DAs' technical knowledge and farmers' practical experience. So far, governmental and regional bodies have meant a limitation to innovative farmers, imposing strict policies as those concerning inputs and selective training. This changed when research institutions started different projects based on farmers' constraints, including them in the formulation of problems and assessment of the results with important success given the level of involvement of local farmers. An integrative approach that puts together all stakeholders' views is thus necessary to boost innovations in the region, which requires as a pre-condition to consider farmers as an essential stakeholder of the system.

On a broader scale, supporting farmers' innovations contributes to build economic and social stability of familiar agriculture, increasing the possibilities of attaining food security at a local and regional level too. Based on the study case, the typology of farmers formed by innovators is less dependent on aid such as the Safety Net than the other two types, specifically type B – subsistence farming –. This suggests that a higher level of implication from local and regional institutions in understanding and supporting local adaptations and innovations is essential to achieve sustainable development. However, it requires solid commitment of research institutions to back up farmers' inclusions in evaluation and planning processes, in order to develop participatory approaches that take into account farmers in agricultural policies and technical issues. This would be of crucial importance at national level too, given the current context of land grabbing in which foreign enterprises are investing in large projects that exclude local populations of working their fields. In the long-term, assuring local adaptation to the problems, stimulating local economy and decreasing farmers' dependence on external aid through diversified farming can increase agricultural production at a national level, assuring food security and contributing to boost exportations.

6.3. RECOMMENDATIONS

Future research on evaluation of performances from farmers' perspective needs to take into account previous experiences and be open to adapt its method to the context since the conception of the methodology. Recent researches based on participatory approaches succeed to involve farmers in the evaluation processes, determining their level of satisfaction on different topics, but often failed in characterizing their practical problems from different angles. This can be solved, firstly, by including farmers in the design of the grid of indicators and the analysis of the results, during the research and after the survey has been completed. Secondly by analyzing jointly quantitative and qualitative information, which complement each other and reveal significant facts and constraints of IS beyond the indicators used. By doing so, a context-specific poll can be undertaken, based on a basic grid proposed that is useful to assess IS in each dimension of irrigated agriculture and a consistent survey that collects farmers' qualitative evaluations accurately.

Concerning the sampling method, even though the stratified random sampling is an accurate, unbiased system and useful to take relevant conclusions, many hypotheses need more samples to be representative. Through a census accurate results can be achieved, allowing testing the hypothesis made by researchers and having thus more representative conclusions. Moreover, through a census it is possible to gain wide experience on water users' perception of IS, contributing to build an improved generic grid of indicators. Finally, further research would be needed on evaluation of impacts and not only of process and output measures, covering the environmental dimension too.

In what refers to the development of the fieldwork and development of the research, it is recommended that is performed by local researchers for two main reasons. Firstly, because by translating the information to the researcher some information is lost, which reduces the chances of fully characterizing farmers' perception on the assessment. Secondly, because local researchers already have the knowledge about the social and political contexts, which can determine more complex and accurate analysis of perceptions and potential of improvement of IS. This can be a large advantage in terms of time and accuracy of the research when identifying the factors that shape farmers perception. Nevertheless, it is preferable to avoid the interference of actors that could have enough contact with the system to have a biased point of view of things and therefore distort the study.

Concerning the irrigation schemes, it is important that Ethiopian institutions, from the local to the regional and state level, realize the importance of including farmers' point of view in improving the performance of IS. Given the current situation of land grabbing in African countries, it seems essential to involve farmers in assessment processes that take into account the real problems experienced in the field to avoid the abandonment of familiar agriculture in irrigation schemes. Furthermore, agricultural planning needs to be based at local level on an accurate monitoring of the agricultural production and performance, instead of taking decisions based on technical expertise without taking into account farmers' performance, which is currently happening. This would imply not only a closer control of DAs activities from the Woreda, but an adaptation of Ethiopian policies that change the paradigm of development into a participatory process that involves all stakeholders of agriculture. Also important is to develop a clear, easy and straight-forward communication system between associations, leaders and farmers, including gujiles, WUAs, WUC and Safety Net. Meetings should be announced clearly and with time to avoid conflicts and weak participation from farmers' side. Similarly, it would be necessary to increase farmers' knowledge about the economic performance through specific meetings. This was suggested by farmers as a solution to increase the economic capacity of the WUAs, and it could lead to new initiatives and discussions about possibilities, based on open discussions that involve the users and not only WUCs.

The irrigation schemes of Gumselassa and Betmera have specific characteristics that deserve specific recommendations related to each IS. For Gumselassa, there is a need to regulate water use by the Woreda or any other legal institution and establish a code of sanctions in case that the rules are not accomplished. Once this is clearly accomplished, it would be necessary to create alternative structures that divert water from the dam to facilitate people washing without jeopardizing water quality. Other necessary measures concerning water management would be the construction of a drainage system and the introduction of drip irrigation. For the former, it would contribute to ameliorate the problems of waterlogging and salinity in the scheme, which is one of the main problems identified. For the latter, drip irrigation would provide an alternative to the current irrigation practices, that would perhaps be more suitable for the IS of Betmera, given their need to save water for irrigation and the problems of salinity at Gumselassa. Indeed, farmers from Betmera pointed out specific problems of quantity and adequacy of water doses, which could ameliorate by increasing the efficacy of water application at the field. Concerning the quantity of water available, it can be stated that heavy deforestation in the mountains of Betmera contributed to reduce the sources of water at the catchment. Therefore, it would be recommendable to start researches about the potential implementation of agroforestry projects, specifically linked to familiar agriculture in the zone. Finally, based on the experience of the field for this research, meetings that gather different WUAs can provide significant improvements in both schemes at different levels. Establishing links between different associations of different schemes (WUAs and informal associations of innovators) would help to enrich farmers' practices and build together solutions to cope with their problems.

The Project EAU4Food can play an important role in achieving significant change, specifically in the irrigation scheme of Gumselassa and on institutional performance at Woreda level. Through diverse field studies, EAU4Food contributes to build knowledge on irrigation schemes of new implementation. In this sense Gumselassa's IS offers several opportunities of research that could help to characterize better the current situation of agriculture in the zone. Taking into account that female-headed households are more vulnerable to poverty, it is recommendable to undertake a study on gender issues in the area, aiming to empower women at local level as a means to assure food security. Furthermore, an analysis of household incomes would be adequate to understand farmers' agricultural decision and what impact in has in irrigation scheme's performance. A cost benefit analysis of the available crops and farmers evaluation of this issue would help to clarify too farmers' choice of crops and facilitate the introduction of high value crops, by studying the main limitations and opportunities that each crops offer. Finally, it seems necessary to undertake further research into the understanding of what circumstances shape the rationale behind farmers' perception, as well as studies concerning their perception over socio-economic, technical and environmental aspects of irrigation.

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ANNEX I. GENERAL OVERVIEW OF SMALL SCALE IRRIGATION IN ETHIOPIA

In order to define accurately 'small scale irrigation systems' it is important to look at the different elements that form this concept. According to Svendson & Small an irrigation system is a "set of physical and institutional elements employed to acquire water […] and to facilitate and control the movement of the water" from the source to the root zone with the aim of enhancing agricultural crop production. This definition describes accurately the features of an IS, remarking its technical and social dimension. It can be added to this definition the key role that the sustainability of the own system plays in its performance in the long term, pointing out the importance of its environmental implications. On the other hand, the concept of small-scale can be framed as one of the three different categories of irrigation scheme that exist in Ethiopia, according to FAO (1995):

I.I. LARGE-SCALE

This type of farms, typically managed by the central government, is of recent origin, being located mainly in the Rift Valley. Similarly to medium-scale irrigation schemes, these schemes are located in zones with relative good drainage conditions, dominated by reddish-brown clayey loams of good water retention capacity and rich in minerals. Regularly found in the Southern Nations, Nationalities and People's Region (SNNPR), these state farms conceived for commercial production are shifting from central management with a coverage of 3,000 hectares to private small-scale management.

I.II. MEDIUM-SCALE

Located generally along the Rift Valley too, medium-scale schemes cover between 200 and 3,000 hectares. They include more than one water users association and require a high degree of government assistance for its development. Hence, there was an evolution in the type of farming, starting with low-cost developments and turning into commercial production of cash crops such as coffee, sugar or cotton.

I.III. SMALL-SCALE

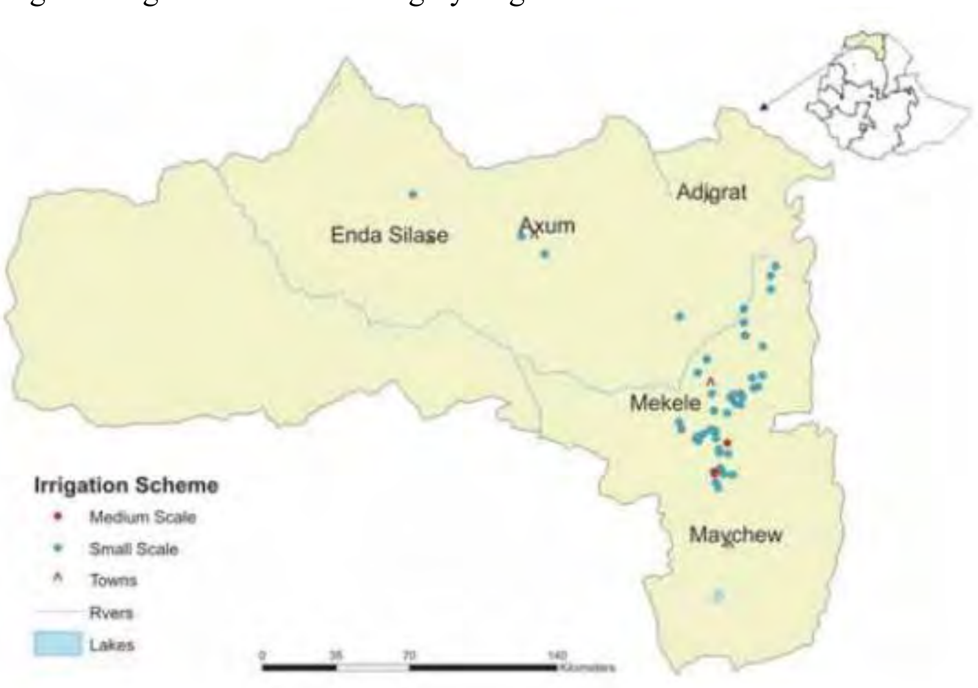
This type of scheme is formed by smallholders grouped in a single peasant association of less than 200 ha in size. Typically their development has been done "on a self-help basis" with little assistance. However, institutions like CoSAERT have been investing in several infrastructures for these types of schemes throughout 15 years, eventually shifting to the current BoANR, institution that registered lower investments in comparison to the previous institution. Given the social and economic importance of small-scale farming in Ethiopia, small-scale irrigation means an interesting opportunity for enhancing food security at a national level. Nevertheless, little is known about the performance of small-scale irrigation systems and achieving positive impact requires sustainable projects in the long term.

Around 80% of Ethiopian population is employed in agriculture. Among them, smallholders cultivate 95% of the cropped area, producing almost 95% of cereals, pulses and oilseeds in Ethiopia. However, most of it is produced by subsistence farmers, whose holdings are of reduced size and often split in several plots. These farmers practice generally rainfed agriculture of low yields. Nevertheless, small-scale traditional irrigation has been practiced as well for centuries in several communities of the highlands, where farmers divert small water streams to irrigate their crops during the dry season. These types of schemes can be found in the northern and southern highlands, in areas with high clay content with deficient drainage. This brownish-gray and black type of soil can be sticky in wet conditions and hard in dry, being difficult to work for local farmers. However, proper drainage systems and agricultural and irrigation practices could help to achieve its high agricultural potential.

ANNEX II. IRRIGATION DEVELOPMENT IN TIGRAY, ETHIOPIA

Irrigated agriculture has been practiced in the Tigray Region since around 500 B.C., starting during the ancient Aksumite civilization of northern Ethiopia in Yeha. Since then, a small number of traditional irrigation schemes have been performing irrigated agriculture by diverting small water streams to their fields, with little knowledge about their performance. According to the CSA (2005), the region of Tigray has nowadays an estimated area of 56,000 km2, with an estimated total population of 4,334,996. Among this population 81.2% account for rural inhabitants, being 18.8 percent urban. Rural population is generally involved in agriculture in Tigray as in the whole country, being mainly rainfed subsistence agriculture. Nonetheless, there are 103 irrigation schemes developed in the Region of Tigray, covering an irrigated area of 4,932.8 hectares. Within this figure, 3,956.80 hectares belong to small-scale irrigation schemes and 976 hectares to medium scale schemes, reporting 22,632 beneficiaries in total.

Fig.20. Irrigation schemes in Tigray Regional State



Source: Awulachew et al, 2007.

Irrigation development in the Region of Tigray involves diverse societies that collaborate either in the investment or management of irrigation schemes. Governmental bodies involved in irrigation development include the Bureau of Water Resources Development and Bureau of Agriculture and Rural Development, organisms that substitute the Sustainable Agriculture and Environmental Rehabilitation in Tigray (SAERT). Furthermore, there exist diverse NGOs and donors that actively participate in the development of irrigation schemes in the region. Among the most relevant are included the Ethiopian Social Rehabilitation and Development Fund (ESRDF), Relief Society of Tigray (REST), World Vision, Raya Valley, Ethiopian Orthodox Church, ADCS (Adigrat Diocese of Catholic Secretariat) and IFAD (International Fund for Agricultural Development) (Awulachew et al, 2007).

Looking at the future, the irrigation potential of the whole country is high; the potential area for irrigation is estimated to be about 3,000,000 hectares. Specifically for the Tekeze basin, one of the major basins of the Tigray Region, where both study sites are located, has an estimated potential for an irrigable area of 83,368 hectares. Covering a total area of 82,350 Km^2, this basin receives water from two main tributaries – Angereb and Goang – that contribute to the Tekeze River, flowing eventually to the Atbarah River, tributary of the Nile. On average, 8.2 BMC are estimated to flow from the river basins, offering a large irrigation potential that is currently being unexploited. With a large amount of surface water with quality suitable for irrigation, it has been pointed out the opportunity that this water offers to grow off-season pasture and forage crops. Some farms of the Rift Valley are already irrigating forage for commercial fattening and dairy farming, activity that has a large and "untapped potential for producing seasonal and long term irrigated pasture and forages" at national level (Mengistu, 2006).

ANNEX III. AGRARIAN SYSTEM DIAGNOSIS

III.I. GENERAL OVERVIEW OF IRRIGATED AGRICULTURE IN ETHIOPIA

As it was stated in the introduction of this study, agriculture is the key driver of Ethiopia's economic growth and the essential basis for assuring long-term food security. Between 15 and 17 percent of Ethiopia's Government outlay is destined to the agricultural sector, comprising 85 % of Ethiopian livelihoods, 43% of GDP and more than 80% of export value (IFPRI, 2010). According to the ATA, Ethiopia's agriculture experienced "consistent growth" since 2003, expanding production the production of staple food crops such as maize (6% per year) among others, attaining the previously mentioned growth of 8% GDP annual growth rate. This production increase has been achieved through public investment that aimed to boost the agricultural sector through different strategies. Firstly, facilitating the access to productive inputs, including improved seed varieties and fertilizers (DAP and Urea). Secondly, establishing over 8.500 Farmer Training Centers (FTCs) and training 63.000 Development Agents (DAs) between 2002 and 2008. These actions from the Central Ethiopian Government are intended to be implemented at local level through the Extension Departments of the Woredas Administration. Even though there has been an improvement of accessibility to inputs, some traditional limitations of Ethiopian agriculture still persist, limiting agricultural sector's growth. Some of these constraints concern the lack of inclusion of farmers in the planning process, specifically for the distribution of inputs, undertaken through a top-down approach. Furthermore, the number of experts (DAs) foreseen didn't attain expectations, with the consequence of a limited and scattered technical support provided to farmers. Other barriers for the agricultural sector are the lack of development of market institutions and mechanisms, gender issues, undeveloped irrigation potential and limited improved inputs available for farmers.

Of crucial importance in overcoming food insecurity is irrigated agriculture, which offers the opportunity of achieving multiple harvests in one year and a large scope for expansion. Ethiopian potential for irrigation is estimated to be more than 5.3 Mha, from which 3.7 Mha belong to surface water sources and 1.6 Mha to groundwater bodies and rainwater management (Awulachew et al, 2007). Currently, 0.7 Mha perform irrigated agriculture in Ethiopia, among which there are the irrigation systems of Betmera and Gumselassa, two schemes with different backgrounds and trajectories but both based on small-scale irrigation. However, little is known about the performances of both IS given the lack of research on these sites, reason why it seems necessary to undertake a quick diagnostic of the study areas, including historical, environmental, agronomic and social aspects to characterize them.

III.II. HISTORICAL CONTEXT

First evidences of Ethiopian agriculture date 8.000 years ago, when first Ethiopian farmers were cultivating sorghum, millet and wheat. The growth of these crops among others as barley and teff has therefore been developed in the Ethiopian highlands since early times, together with other practices as herding. Since then, different innovations and adaptations took place, improving the agricultural development. Among them has special importance irrigation, which allowed the steady increase of production and productivity that meant a true revolution in agriculture. Irrigation has been practiced in several specific schemes of Ethiopia since at least 500 B.C. (Solomon & Kitamura, 2006), and some of these traditional irrigation schemes still perform, adapting to diverse climatic, social, political and economic circumstances along the way. However, there is no documented history on water management for agriculture in Ethiopia. Thus, little is known about irrigation techniques and social arrangements about water management since its starting date more than 2.500 years ago. It was in the 20th century that took place the steady emergence of irrigation development along with the establishment of agro industrial factories. This agricultural evolution was importantly influenced by the changing political context, which passed through monarchic, dictatorial and democratic regimes, having significant impact on their performance.

During the Feudo-Bourgeois regime of Haile Selassie, irrigated agriculture covered a small area, contributing minimally to achieve Ethiopia's food self-sufficiency. Land policies of the time prevented small-hold farmers to invest in irrigation, given that land was owned by a small landlord-elite, whereas farmers were just tenants, which limited irrigation's development in the country. In 1975, the communist regime of the DERG achieved the power, changing the previous land policies and declaring land under public ownership, boosting therefore small-scale and large-scale irrigation schemes in Ethiopia. However, deficient design and construction together with poor irrigation management led to underperformance of the schemes, failing to meet the objectives set (Barghouti & Le Moigne, 1990). Today, Ethiopia is ruled by a democratic government, experiencing fast economic and demographic growth and setting ambitious plans of expansion of irrigated agriculture, but its agriculture still remains underdeveloped. Even though its large potential, cyclic droughts, low level of technology and weak infrastructures prevented the agricultural sector from achieving the levels of production and productivity targeted. Nevertheless, other factors of social nature also played a role in the low performance of small-scale irrigation, specifically in new irrigation schemes implemented by State initiatives. For instance, the lack of feeling of ownership from farmers' side had had considerable impact in irrigation schemes' management, concerning practical aspects such as the operation and maintenance of the canals (at scheme level) and irrigation practices (at plot level), which influence notably in the achievement of good performances and therefore high productivities.

III.III. SOILS AND TOPOGRAPHY

Ethiopia's topography is characterized for being "extremely varied" (FAO, 1984d; Alemayehu, 2006, Awulachew, 2007), registering altitudes that range from 126 meters below sea level in the Depression of Dallol (Afar), to the mountain Ras Dejen in the Semen Mountains, raising to 4.620 meters. It is formed by a highland plateau that varies between 2.000 and 3.000 meters along the center and northern part of the country. This plateau is bisected diagonally by the Great Rift Valley, a continuous geographic trench that crosses the country from the south-west up to the Depression of Dallol in the northeast. The Ethiopian plateau, which goes down to Sudan and Somalia, generally has regular rainfall and fertile lands where typically coffee and Mediterranean and tropical crops are produced. This topographic diversity has resulted in a “multitude of agro-ecological zones and sub zones” where varied farming systems take place (Alemayehu, 2006). Given the rich variety of topographic and climatic factors as well as parent material and land use, Ethiopian soils present a wide diversity (FAO, 1984e), identifying up to 19 different soil types according to the Ministry of Agriculture, prevailing mainly lithosols, nitosols, cambisols and regosols.

Previous research on Ethiopian lithology stated that the fertility status is, in what concerns Potassium, Nitrogen, Cation Exchange Capacity (CEC) and organic matter contents, generally higher by international standards (EARO, 1998), even though phosphorous content is assessed low to very low. Indeed, when comparing soils in the highlands of Ethiopia to the African standards, most of them are considered fertile, given their capacity to retain the nutrients at depth (FAO, 1984c). Nevertheless, it has been stated that soils of Ethiopian highlands lack nitrogen and phosphorous among other important nutrients, reason why high crop yields cannot be produced unless fertilizers are supplied (Alemayehu, 2006). Based on these guidelines, Ethiopia’s Government has started a top-down plan to foster agricultural increase of crop production based on irrigation projects and the use of fertilizers. However, the expected results were not achieved in drought prone areas as the study areas of this research, where farmers are obliged to buy fertilizers to have water access even though the amount of water received is not adequate to their CWR.

More specifically, the areas studied in this research are located on the highland areas of the southern part of Tigray. The irrigation scheme of Betmera is located in a mountainous area, precisely in an undulated valley formed by sandstone and basaltic rocks, having each type of mountains at both sides of the valley. The fields cultivated are regosols, which are soils developed on unconsolidated materials, altered and of fine texture. This is a type of soil suitable for an ample range of crops under irrigation and for grazing. However, these soils suffered a long erosion process that influenced in the loss of organic matter and fertility, mainly due to the deforestation of the zone. Some forests remain in the slopes of the mountains, namely eucalyptus, juniper, acacia, pines, euphorbia and cactus. The scheme of Gumselassa is situated in the midlands found at the north of Betmera. It is an undulated plateau of sandstone that suffered heavy erosion processes, located between the soft hills of Arra and Wombertaot and the village of Adigudem. This erosion is mainly provoked by water incidence coming from the mountains and flash floods occurring during the rainy seasons, leaving important gullies as it can be seen in the picture showed below.

Fig.21. Plateau of Arra-Alemsegeda and village of Arra

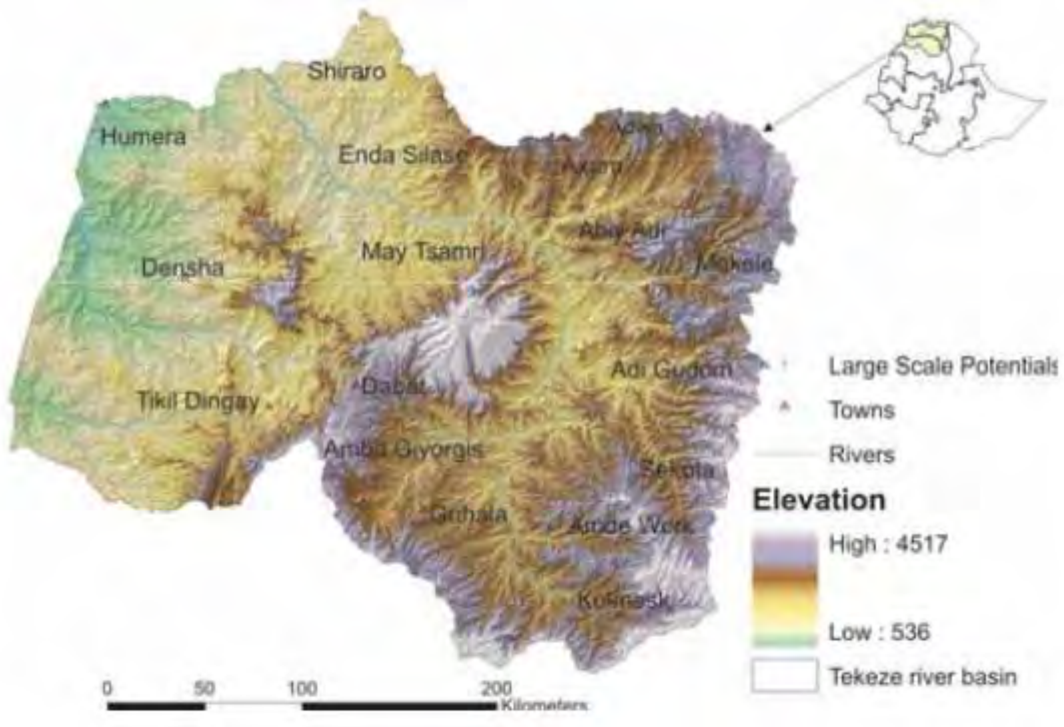
Source: Javier Rodríguez Ros

Nevertheless, wind erosion also plays a key role, contributing to remove valuable soil and therefore impoverishing soil fertility of the zone. It can be stated that this is a consequence of the heavy deforestation occurred in the area, that not only is affecting agriculture at the plot level, but is also enhancing the probabilities of occurring flash floods and decreasing the capacity of the storage, given the siltation processes that carry soil to the dam. Concerning the irrigation scheme, the types of soils present are vertisols, cambisols, luvisols and regosols, heterogeneously distributed within the scheme.

Hydrology

Ethiopian hydrography is strongly influenced by the Nile River and its tributaries as well as by the monsoon. It can be stated that Ethiopian highlands are the source of much of the river flow of the Blue Nile, contributing with more than 60% of Nile flow (Ibrahim 1984; Conway and Hulme 1993) and even increasing this contribution to 95% during the rainy season (Ibrahim 1984). Moreover, there exist various aquifers in the highlands, what together with the rainfall allowed the development of diverse agricultural systems. Particularly for the Tigray Region, the amount of water that annually runs off through three major drainage basins is "estimated to be more than 9 billion m3" (Solomon & Kitamura, 2006). It is formed by three major drainage basins: Tekeze Basin 8.2 billion m3, Mereb Basin, 0.65 billion m3, and Dennakil (Afar) Basin, with an annual flow of 0.86 billion m3 (Awulachew, 2007). Run-off of both study sites researched is located in the Tekeze Basin, of an irrigation potential for large scale irrigation schemes of 83,368 hectares. Ground water resources are not particularly developed in this area, given its reduced potential identified. Nevertheless, the area where the irrigation scheme of Gumselassa is located offers larger potential in this sense. Thus, the Woreda of Hintalo-Wojirat has boosted the construction of shallow wells and deep wells to complement irrigation activities. These actions didn't attain the expected results from farmers, given the difficulties that they had in using these wells. Farmers require pumps to irrigate their fields, which means an extra cost and many farmers are not willing to undertake. Furthermore, there's a lack of tradition of groundwater irrigation, which causes farmers' difficulties to reach perform irrigation activities from a technical and social perspective and institutions' incapability to provide solutions. However, some farmers of the downstream part of the scheme had the initiative to rent motor-pumps in groups of five or six farmers and irrigate per turns organized by them, which means an innovation in water management of the area. Concerning the shallow wells built by the administration together with the PSNP, they have available manual pumps that could be used by farmers, but they have not been supplied yet due to the administration passivity and the reduced economic capacity of most of farmers.

Fig.22. Irrigation potential of Tekeze Basin



Source: Awulachew et. al., 2007

Specifically for the irrigation scheme of Gumselassa, the mean annual surface runoff from the catchment is 2.59 Mm3. The amount of water available for subsurface and base flow in the upper part of the catchment is 0.22 Mm3, being 0.925 Mm3 the amount of water that percolates in to the ground through the reservoir bed. This figure represents the amount of water that flows towards the command area as subsurface and ground water flow. Concerning hydraulic structures, the irrigation scheme accounts for a main earthen dam, a spill way, two main gate – from which one is out of service currently –, two main canals, drop structures and division boxes – five along the primary canals –.A small part of the main canals was lined by Co-SAERT, activity that is being resumed by current administration for the left canal. Excess water from the plots runs to the main drain through a deficient drainage system, flowing seepage water downstream, were an informal association of farmers use this water for irrigation.

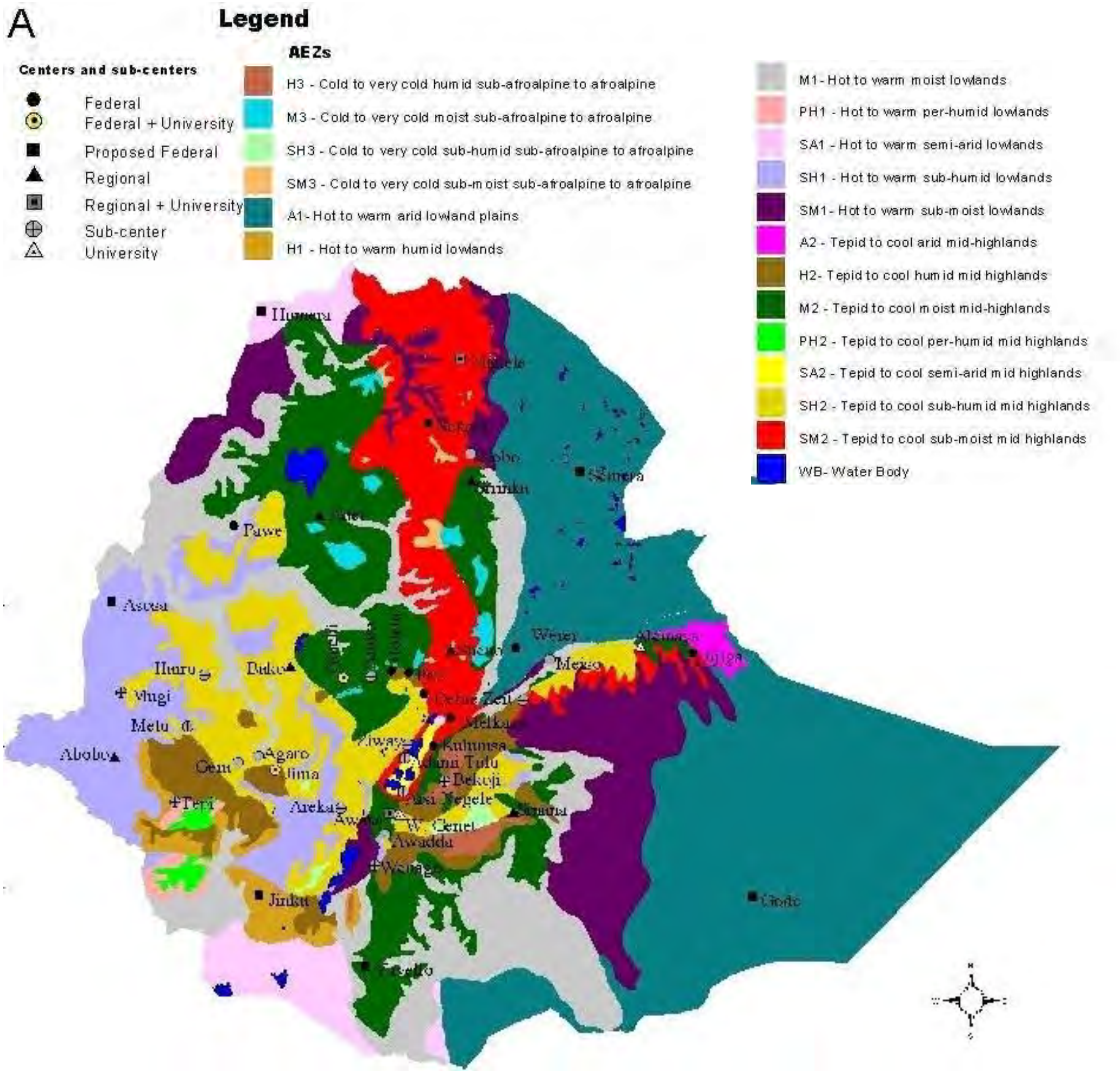
All in all, it can be stated that there has been a progressive degradation of the natural resources in both study sites, caused mainly by climate variability and food insecurity, which lead to expand the agricultural use of the soil to maximize crop production particularly at the end of the nineteenth century. This problem affected the whole country, which was once treed with "about 34% of its area and 57% of the land above 1,500 meters" covered by dense forests (Woldu Z., 1999). Intensive deforestation decreased the forest area down to 3.6% of the total area and to 9% of the land above 1,500 meters. This deforestation induced by human action contributes to land degradation and desertification in the area, provoking an important impact at the hydrological level. The effects include:

- Decrease of organic matter in the soil, which affects negatively to the water retention capacity of the soil.
- Instability of the water flow due to poor water retention, which can lead to flash floods.
- Increased soil erosion and sedimentation in the rivers, with important consequences for irrigated agriculture.

III.IV. Climate and Agro-ecological zone

In terms of climate, Ethiopia can be also framed as a heterogeneous country. As stated above, Ethiopia has a broad altitude range, which added up to its location - near the equator - create the wide climatic diversity of the country, allowing for different agricultural production systems.

Fig.23. Geographical distribution of Ethiopian Agro-ecological zones



Source: Mengistu A., 2006

One of the key factors that determine the distribution of climatic factors and land suitability is altitude. Altitude influences on the "crops to be grown, rate of crop growth, natural vegetation types and species diversity" (Mengistu, A., 2006). The Ethiopian plateau occupy vast areas where mean annual temperatures range between 10° and 20° C. In these areas – where both study sites are located – above 1.500 masl average annual rainfall is normally above 900 mm. Even though erratic rainfall hinders agricultural planning, it can be stated that "a substantial proportion of the country" has enough rain to assure rainfed crop production (FAO, 1984b).

Table 11. The Current Major Agro-ecological Zones of Ethiopia

No.	Code	Zone
1	A1	Hot to warm-arid lowland plains
2	A2	Tepid to cool arid mid highlands
3	SA1	Hot to warm semi-arid lowlands
4	SA2	Tepid to cool semi-arid mid highlands
5	SM1	Hot to warm sub moist lowlands
6	SM2	Tepid to cool sub moist mid highlands
7	SM3	Cold to very cold sub-moist sub-afroalpine
8	M1	Hot to warm moist lowlands
9	M2	Tepid to cool moist mid highlands
10	M3	Cold to very cold sub-afroalpine to Afroalpine
11	SH1	Hot to warm sub humid lowlands
12	SH2	Tepid to cool sub humid mid highlands
13	SH3	Cold to very cold sub-humid sub-afroalpine to Afroalpine
14	H1	Hot to warm humid lowlands
15	H2	Tepid to cool humid mid highlands
16	H3	Cold to very cold humid sub afroalpine to afroalpine
17	PH1	Hot to warm per-humid lowlands
18	PH2	Tepid to cool per-humid highlands

Source: MoA, 2000

Among the Major Agro-ecological Zones considered in Table__, the irrigation scheme of Betmera can be classified in the group M2: Tepid to cool moist mid highlands. It is located at an altitude of 2.500 masl, and registers a slightly lower temperature than Adigudem (19ºC), where temperature samples have been traditionally taken for this scheme. Thus, this IS can be classified in the traditional AEZs as Dega, typical from highlands (between 2.500 and 3.500 masl) with an average rainfall between 900 and 1.000 mm and a temperature between 14-18ºC.. Agriculture is in most of this area rain-fed, which means that they rely on the kiremt rains and on the belg rains. On the other hand, the irrigation scheme of Gumselassa is framed on the SM2 AEZ, traditionally called ‘dry-Weynadega’ and typical from the midlands. This group is framed in an elevation range of 1.500-2.500 masl, rainfall between 900-1.000 mm/year and a mean temperature between 18ºC and 20ºC.

III.V. CROP SYSTEMS

Crop production has a key role not only in attaining food security in Ethiopia, but also in providing inputs for the industrial sector and fostering exportations. In 2010/11, crop production accounted for 31.5% of Ethiopian GDP, decreasing to 30.4% in 2011/12. It can be therefore stated that increasing crop production not only boosts agricultural outputs, but also Ethiopian GDP, reason why it is a key sector in Ethiopian and SSA development. Concerning agricultural outputs, crop production accounts in Ethiopia for 60% of it, leaving 30% for livestock production and 7% for forestry. Almost 87%of crop production comes from cereals, with a large difference with pulses and other crops. However, other crops such as chick pea, beans or sugar crop have increasing food and industrial value.

Table 12. Area coverage and production of major food crops in 2011/12 fiscal year

	Area cultivated in million hectare				Production in million quintal			
	Smallholder farmers (Meher)	**Smallholder farmers (Belg)**	**Commercial farms**	**Total**	**Smallholder farmers (Meher)**	**Smallholder farmers (Belg)**	**Commercial farms**	**Total**
2010/11	11.82	1.17	0.45	13.45	203.48	9.01	9.33	221.82
Cereals	9.69	0.93	0.18	10.8	177.61	8.05	6.11	191.77
Pulses	1.36	0.21	0.013	1.59	19.53	0.94	0.22	20.69
Oilseeds	0.77	0.03	0.26	1.06	6.34	0.02	3.00	9.36
2011/12	12.1	1.17	0.42	13.69	218.57	6.82	7.05	232.44
Cereals	9.58	0.89	0.18	10.65	188.09	5.81	4.92	198.82
Pulses	1.63	0.26	0.03	1.92	23.16	1.01	0.45	24.62
Oil Seeds	0.89	0.02	0.21	1.12	7.32	-	1.68	9

Source: GTP 2012

The main rainfed crops cultivated at Gumselassa are teff, wheat, red wheat and barley. However, sparse innovative farmers may cultivate onions and rice during the rainy season too, aiming to cope with salinity in the case of rice and testing alternative management practices for onions. During the dry season thanks to irrigation farmers are able to grow a larger variety of crops, among them being the most cultivated: maize, red maize, onion, potatoes, vetch, garlic, tomatoes and chickpea. In the irrigation schemes of Betmera the number of crops cultivated is higher, including cash crops such as gesho, coffee or qat and a variety of food crops. Major food crops grown during the irrigation season in Shanfa Geladis and Mai Tebatu are maize, onion, potatoes, vetch, garlic, tomatoes, cabbage, vegetables, carrots, sorghum, gesho, beans and peas.

In the WUA of Shanfa Geladis some farmers grouped in an informal association perform innovative farming, growing fruit crops like avocado, orange, mango or papaya. During the rainy season the crops cultivated don't differ from Gumselassa's ones, being teff, wheat and barley the most extended crops. Therefore, it can be stated that the main differences between both schemes rely on irrigated agriculture management, starting from the choice of the crops. Other differences concern practical irrigation management, in terms of hours of water distribution to the plot and flexibility of the managers to give extra water turns. Concerning crop's irrigation patterns, both irrigation schemes perform similarly. Irrigation practices are summarized for the main crops as follows:

- Onion: after the fourth day of being planted onions need to be irrigated. Next turn should be applied one week later. Later on they have variable water turns, some each month and one week, some each three weeks, depending on farmers' criteria, water availability and water managers' decision.

- Potatoes: requires water when is planted and after that for irrigation turn each two weeks. At flowering state, potatoes need for additional water,

- Tomatoes: need irrigation turn at the seedtime, thereafter farmers use to irrigate them each ten days.

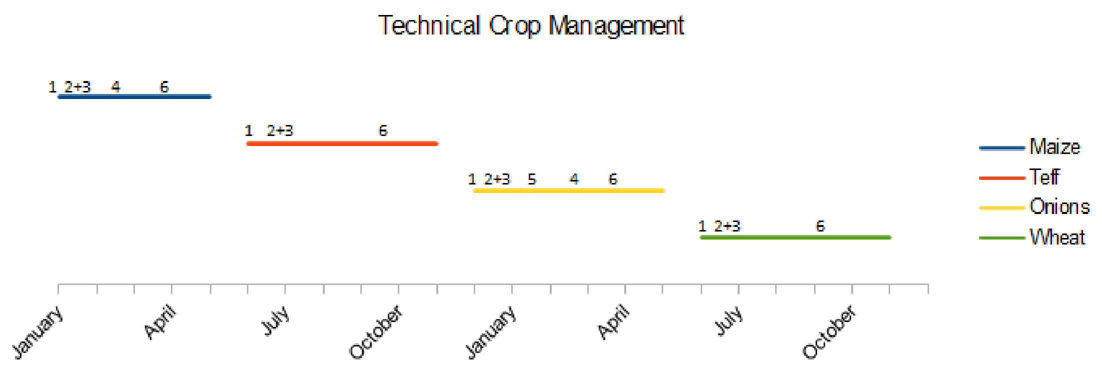
- Maize: this crop, often planted in association with onions, has slight lower water requirements than them from farmers' perspective, being irrigated around each three weeks or one month.

- Vetch: this crop requires just three irrigation turns along its lifecycle.
- Teff: requires a considerable amount of water during the rainy season. If not farmers think about planting vetch to increase the fertility of the soil.

Technical Management

In what refers to crop management for common crops in both study areas, it can be stated that they have similar practices and approaches. Thus, a typical two-year crop rotation based on maize, teff, onions and wheat would show similar characteristics in both irrigation schemes. Planting date of maize can be done in a one month rage between December 15th and January 15th, depending on farmers' needs, water availability and start of irrigation for each scheme. Concerning the use of fertilizers, DAP is applied together with the seeds at the sowing date, being Urea applied one month later. According to farmers' extended practices, maize requires three previous plowing before planting. Even though it can be irrigated through furrows, most of farmers interviewed irrigate maize by flood irrigation. During the growth of maize little activities are performed, including weeding and irrigation management. The harvest is done four months later, either in April or May, when the irrigation season finishes. Even though some farmers leave their fields fallowing during the rainy season (specifically farmers with problems of salinity in Gumselassa), a large majority of farmers cultivate right after the irrigation season, leaving in between a variable space of time in which they plow their plots. The rainy season starts around the middle of June, occurring first rains before in the mountains than in the plain, where the IS of Gumselassa is located. Therefore, the planting date for the next crop in the rotation – teff – is done between mid-June and the first week of August. Before teff is planted, farmers generally perform four plot plows – more than any other crop – to prepare the field. Thus, the cultivation of teff can last until November, blocking the possibility to plant for instance chickpeas or other pulses in September, which would make three harvests within a single year.

Fig.24. Technical Crop Management for a typical crop rotation



1: Plowing activities
2: Sowing
3: Application of fertilizers
4: Weeding
5: Application of pesticides
6: Harvest

Source: Own elaboration

Next crop in the typical rotation considered is onion, a crop that often is associated with maize, tomatoes or potatoes, specifically for the latter in the irrigation scheme of Betmera. Onions require three plows before its plantation. This occurs, similarly to maize, in December-January, being sowed at the same time that DAP is applied. Concerning Urea, farmers do a localized application digging around the onions. These are generally planted in furrows, with little space between the onions because, from farmers' perception, there're more chances to harvest wholesome onions than planting them with more space – as suggested by DAs –, given the existing problems of 'mugella' and 'hamudia' with onions. In order to cope with this problem, farmers use to apply Malathion and Finitrothion to the onions, even though the results don't fit farmers' expectations. In the months of April and May, farmers harvest the onions and start the preparation of the next cereal crop, wheat, which requires three plows before its seeding. The activities required for all cereals are similar; changing only according to farmers' practices the number of times that the plot is plowed. Thus, barley is a typical crop planted in the whole Region that requires only two plows, which in contrast to teff offers lower costs.

Production costs play a key role in agricultural activities of both sites, being crucial specifically for female headed households. Female farmers complained about the fact that for them is extremely hard to plow the land and not always well regarded, reason why they have to hire workers to plow their plots. The cost of hiring a worker for plowing is of 100 birr per day, including the oxen necessary for the activity in the case that farmers don't have them. One plot can be plowed within one day given the reduced size of the plots (0,25 hectares), requiring only one man for its performance. Furthermore, many farmers use to hire people for the harvest as well, which has a cost of 150 birr per day. In this case, more seasonal workers are required, reaching up to 10 workers for the harvest, even though many of them use to be familiars or children. All these costs have to be added to the purchase of inputs (seeds, fertilizers and pesticides), which not always are adequate to farmers' needs. From the Department of Extension of the Woreda of Hintalo Wojirat, the available vegetable seeds are: tomato, cabbage, chard, lettuce, carrot, potato, onion, garlic. However, there are shortages of tomato, cabbage and carrot, which are not as much planted as they are in the irrigation scheme of Betmera. On the other hand, farmers are demanding improved seeds specifically for wheat and maize, HAR2501 and Pica Flora respectively, given their resistance to droughts. Other crops particularly demanded by farmers are tomato, onion and potato, three crops traditionally cultivated in the irrigation schemes of both IS. Crops like vetch are not supplied by local administration but locally available to farmers. In what refers to pesticides, the Woreda of Hintalo Wojirat offers, according to them, a wide range of products including Malathion, Finitrothion, Diamotate, Dersuban, Diazinol 60% (against boll worm & cut worm), Karate (against rust), Endosulfhan, Acatlic 2% (for weevil i.e. storage pest), zinc phosphate (for rodents), 2.4D (herbicide) and tilt (against mugella). Farmers are demanding according to the administration mainly four products: 2.4D, Malathion, Finitrothion and Diazinol. In the case of Betmera, pesticides are of difficult access for farmers, given the conflict with honey-bee producers, so the quantity and availability of pesticides is reduced to Malathion, Finitrothion and 2.4D. Nevertheless, farmers stated that some of the inputs supplied by the government affect the quality of the water and influence on the slow growth of their crops. In order to solve this situation, they claimed to the administration for alternative inputs that weren't offered, according to farmers' view.

Technical performance of crop systems

According to Eyasu (2005), the rainfed crops cultivated in Gumsalasa irrigation command area include wheat with coverage of 37%, teff (31%), barley (29%) and vetch (3%). The actual productivity values of the first three aforementioned crops are 840, 470 and 770 kg/ha, respectively. The sowing date of those crops start mid of Jun, 20th July, mid of jun, and 20th August, respectively.

Table 13. Productivity of selected crops in 2010/11 and 2011/12 fiscal year

Crop type	Productivity in 2010/11 (Quintal per hectare)				Productivity in 2011/12 (Quintal per hectare)			
	Smallholder farmers (Meher)	Smallholder Farmers (Belg)	commercial farms	Average	Smallholder farmers (Meher)	Smallholder farmers (Belg)	Commercial farm	Average
Major Crops	17.2	7.67	20.62	16.49	18.08	5.82	16.65	16.99
Cereals	18.32	8.64	33.62	12.42	19.61	6.51	26.69	18.64
Teff	12.6	5.55	14.48	12.42	12.80	4.18	14.28	12.58
Barley	16.27	6.94	24.75	15.03	16.72	5.77	24.43	15.24
Wheat	18.38	9.85	33.03	18.41	20.28	8.91	26.19	20.07
Maize	25.39	9.50	48.05	22.5	29.53	7.15	31.48	25.11
Sorghum	20.85	7.0	24.06	20.5	20.53	2.99	23.52	20.03
Pulses	14.38	4.3	16.29	13.05	14.32	3.87	15.92	12.91
Horse beans	15.19	4.7	17.50	15.10	15.62	1.90	17.29	15.47
Field Peas	12.60	6.61	23.70	12.39	12.36	5.28	15.02	11.88
Haricot Beans	14.33	4.55	17.14	10.18	11.69	3.85	17.51	8.73
Chick-peas	15.49	2.39	15.97	15.12	17.30	9.90	15.76	17.06
Oil Seeds	8.18	0.55	11.66	8.83	8.29	-	7.96	8.10
Neug	5.8	-	6.5	5.85	6.02	-	6.93	-
Linseed	8.8	-	17.88	8.83	9.67	-	15.83	9.60
Groundnuts	14.43	-	17.20	14.47	16.05	-	15.88	15.05
Sunflower	9.23	-	17.99	9.34	10.85	-	17.99	12.16
Sesame	8.52	0.61	11.67	9.45	7.25	-	7.67	7.30

Source: GTP 2012

According to Eyasu (2005), the productivity of irrigated maize, onion and tomato are 5085, 9397, and 1570 kg/ha, respectively, which according to farmers' perception can be sensibly lower.

III.VI. AGRARIAN SYSTEM

In the previous section it was analyzed the traditional classification that divides the Ethiopia into different AEZs based mainly on altitude and rainfall. Nevertheless, each zone is characterized as well by economic activities, population density and other socio-cultural features such as cropping and livestock rearing patterns. Ethiopia's livestock production is said to be one of the largest in Africa and a large contributor of Ethiopian economy. Livestock population has been growing along the last ten years, reaching 50,000,000 cattle and

50,000,000 sheep and goats together in 2008 (CSA, 2008a). Furthermore, poultry production is extended in the whole country, accounting each household dedicated to agriculture for at least two or three chicken in their farms. Given the key role of livestock production, it can be assumed that grazing has occupied traditionally an important position in land distribution in Ethiopia. Ethiopian land tenure system is regulated by the national rural land proclamation No. 89/1994, which establishes some users' rights beneficial for familiar agriculture in own cultivated and grazing lands, communally used by pastoralists. This proclamation sets the land "shall not be subjected to sale or to other means of transfer", having the administration the property of land. However, land redistribution has been performed periodically, being a serious disincentive to undertake any improvement on erosion control measures, of crucial importance as explained for the hydrology of the zones studied.

In this context, Ethiopian production systems are complex, given the diversity of AEZs and the cultural diversity of its people. Land holdings are of reduced size and often divided into many parcels: around 26% of agricultural land is formed by farms of less than a hectare, almost 60% of less than two hectares and the rest is formed by holdings between 2-2.5 hectares. Specifically for the Tigray Region, the main agrarian system is familiar subsistence farms, typical of all Ethiopian highlands. However, agricultural products of familiar agriculture are also privately traded in local markets, with low involvement of the public sector. Thus, the main agrarian system found can be framed as 'Small to medium scale crop-livestock production'. These systems are found in the so called most productive zones dega and woynadega. In these AEZs a wide range of crops can be grown and many species of livestock breed for different objectives. Thus, production systems are a formed by crop plus livestock production, including here different animal production. Given the erratic rainfall, irrigation plays a key role in these areas, assuring two crops per year or even three in some areas, which means a major change in agricultural performance of Tigrinyan farmers. These areas, similarly to the rest of Ethiopia and Tigray, have a high population, which determines the smallholding nature of its farming.

Other agrarian systems that can be found in Tigray, are 'Smallholder crop production', 'Small to large-scale livestock production' and 'Major agricultural enterprises'. The first one is present in the higher part of the mountains, were plants are adapted to moisture deficiency, given the high transpiration caused by intense radiation. These systems rely often on barley cultivation, being possible to grow two crops per year when rainfall is above 1,400 mm/year. Cattle serve as farm power in this type of system, even though there are sheep as the main livestock production too. The second main agrarian system is typical of zones of low altitudes, between 1,500 and 500 meters. Given the reduced rainfall typical of these areas, only drought resistant crops can be grown, with the exception of irrigation schemes where possible. Hence, livestock production is extended and essential to sustain local livelihoods there. Lowlands are inhabited by pastoral people of the eastern part of the region who depend on livestock, providing subsistence through a source of meat, milk and fiber for its population (Mengistu, 2006). The last system, 'Major agricultural enterprises', consist of previous state farms of the communist regime that have been progressively privatized along the past 20 years. Private investments have been performed specifically in the agro-industrial sector, fostering cash crop and livestock production. Moreover, medium–scale private crop production is beginning as a result of the recent state farms privatization and new investment policies, as it happens for instance in dairying farms found around big towns such as Mekele.

ANNEX IV. FARMERS' SURVEY

Introduction of research (1 min)

- Personal introduction
- Context of the study
- Explication of the anonymous condition of the informant

Identification (2 min)

a. Gender: M/F
b. Household size:
c. 'Tabia':
   - Village:
d. Experience in agriculture (years):
e. Experience in irrigated agriculture (years):
f. Start of farming at GS/B-H (year):
g. Source of water:
h. Participation in any collective/association of farmers: Y/N
   1. *If yes, which:*

i. Knowledge about operational rules: Y/N

Land and crops (3 min)

<u>Land</u>

b. Location of the plot/s
   - *Gumselassa: Upstream/Middle/Downstream – Right bank/left bank*
   - *Betmera: A/B/BL/C*
c. Landholding size:
d. Ownership: Owner/Share cropping
   - Other:

<u>Crops</u>

e. Type of crop/s:
f. Rotation: Y/N
   - Which:
g. Inputs:
   - Fertilizers: Y/N
     1. *If yes, which:*

- Insecticides: Y/N
  2. *If yes, which:*
- Pesticides: Y/N
  3. *If yes, which:*

h. Irrigation practices: Flood/Furrow

External factors (2 min)

Financial resources

a. Credit: Y/N
   1. *If yes, by whom:*
b. Economic activities (off-farm wage income): Y/N
   1. *If yes, which type:*

Marketing

c. Location of commercialization of the products:
d. Transport to market:
e. Commercialization of products through Cooperative: Y/N

Opinion poll (15 - 20 min)

Thereafter, each indicator will be explained to the farmer and for each of them he will have to choose one of the numbers within the table detailed below:

-7	-6	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	+6	+7

The Irrigated System

Source of Water

1. Quantity
2. Quality

Water Quality Service

3. Adequacy
4. Predictability

5. Tractability
6. Flexibility
7. Equity

Group Dynamics

8. Participation
9. Fund generation
10. Social support
11. Group atmosphere
12. Operation & maintenance

<u>The Irrigated Agricultural System</u>

Quality of Soils

13. Soil structure
14. Fertility
15. Salinity

Diseases

16. Insects & pathogens

<u>The Agricultural Economic System</u>

Financial resources

17. Availability of inputs
18. Accessibility to credit

Market context

19. Adequacy of prices

Technical assistance

20. Accessibility
21. Effectiveness

After the selection of a number in the satisfaction index for each indicator:

What is the main problem concerning this indicator, if any?
What would be according to you the solution for that problem?

Additional questions:

Is there any other indicator that you believe essential and we did not include?
How can this evaluation be improved in order to better evaluate irrigation systems' performance?

Complementary questions (2 min)

a. Age:
b. Educational level:
   - *Other:*