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School of Graduate Studies

M.Sc. Thesis on

Characterization And Performance Evaluation of Fentale Irrigation Development Project

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Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Hydraulic Engineering)

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DECLARATION

Here with I declare that this thesis is my work and is done only using by sources and materials that are duly acknowledged and clearly indicated. This thesis has never been submitted in an equal or similar version to any other examining board for award of any degree or diploma to the best of my knowledge and belief.

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As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by Beyenech Bisrat Mekonnen, entitled:

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I recommended that it be accepted as fulfilling the thesis requirement.

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As a member of the Board of Examiners of the MSc, Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by Beyenech Bisrat and examined the candidate. We recommended that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Civil Engineering (Hydraulic Engineering).

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But the whole glory is given to the almighty God!

ABSTRACT

Evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. This study was carried out at FIBIDP with the objectives of characterization of the project, evaluating its performance using selected performance efficiency indices and analyzing water productivity in terms of water applied and water consumed for future improvements. While conducting this study first, initial assessment and field observation, consultation with different stakeholders was made to visualize the study area. The scheme characterization and performance evaluation was made by comparing the functionality of the structures with the design and by measuring the canals discharge capacity, dimensions, length of flow, using selected performance indicators such as conveyance, application, storage and distribution uniformity efficiencies along with the water productivity in terms of water use efficiency respectively. Most of the structures found on main canal are in need of maintenance. The most problem of this project was not only timely completion but also frequent revision of design and shortage of budget that made the project under performance. Average conveyance efficiencies on lined and unlined canals were obtained as 95%, 51%, respectively. The application efficiencies were 56.0%, 68.4% and 72.9% in head, middle and tail end location of the scheme respectively. The water storage efficiencies For upstream 97.7%, For Middle stream 98.0% and For downstream 98.8%. Water productivities in terms of water applied for the three locations (head, middle and tail) test plots were obtained in the order of 12.1kg/m³, 18.1kg/m³ and 20.3kg/m³. Finally, the economic water use efficiency of test plots in terms of benefit-cost ratio were estimated and found as 2.66, 2.76 and 2.15 for head, middle and tail locations, respectively and found to be efficient. Hence, it could be concluded *that productivity of the cropping system can be improved by minimizing water losses.*

Therefore, the major recommendations are forwarded for sustainable resource utilization. Timely design, construction, and timely maintenance of irrigation structures contributes for equity of water distribution among farmers at different locations and achieving the most plan of production. Preparation of extra drainage system is necessary for the scheme to avoid accumulation of excess water in the lower spots that leads to deep percolation loss.

Key words: *Characterization, Efficiency, FIBIDP, Irrigation, Performance*

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ACRONYMS

AAIT	Addis Ababa Institute of technology
AMS	Actual soil moisture stored
CARE	Cooperative for American Relief Everywhere
CUC	Christiansen uniformity coefficient
CWP	Crop Water Productivity
CWR	Crop water requirement
Da	Applied Depth
Dmin	Minimum infiltrated depth
DPR	Deep Percolation Ratio
Du	Distribution Uniformity
Ea	Application efficiency
Ec	Conveyance efficiency
EE	Effective Efficiency
E_O	Overall irrigation system efficiency
Er	Storage efficiency
ET	Evapotranspiration
Eta	Actual seasonal crop water consumption
Etc	Crop evapotranspiration
ETo	Reference evapotranspiration
E_S	Scheme irrigation efficiency
EWP	Economic Water Productivity
FAO	Food And Agriculture Organization
FIBIDP	Fentale Irrigation Based Integrated Development Project
FC	Field Capacity
GDP	Gross Domestic Product
GPS	Global positioning system
Kc	Crop Coefficient
LSI	Large-Scale Irrigation

MoARD	Ministry of Agriculture and Rural Development
MSF	Metehara Sugar Factory
MSI	Medium -Scale Irrigation
NMSA	National Meteorological Services Agency
OIDA	Oromiya Irrigation Development Autority
OWWDSE	Oromiya Water Works Design and Supervision Enterprise
RWH	Rain Water Harvesting
SSI	small scale Irrigation

1. INTRODUCTION

1.1.Background

In countries like Ethiopia where poverty is widespread, low farm productivity and degraded natural resources are the major problems, the need to use irrigation water in agricultural system is not questionable. Small-scale irrigation has been chosen by most donor agencies and development partners as a strategic intervention to address food security in Ethiopia. A number of factors led to this choice, the most obvious of which is that irrigation increases the potential for producing more food more consistently in the drought-prone food insecure areas.

The central role of irrigated agriculture within the context of poverty reduction, efforts of the country is well understood as it increases the production of agricultural raw materials, exploit land and water resources with enhanced sustainability, reduce dependency on rain-fed agriculture and its vulnerability to erratic rainfall prevailing in the country and avoid the shattering consequences of periodic drought (MoWR, 2002).

Recognizing the urgent need of enhancing agricultural production, the Federal Democratic Republic of Ethiopia have taken a number of measures to bring more and more area of arable land under irrigation by implementing a number of irrigation development schemes.

To overcome such problems, the Oromia Regional Government also has identified schemes, which are presently under different phases of study and implementation. Fentale Irrigation Based Integrated Development Project (FIBID) is one of the large-scale irrigation projects, which is planned by the regional government of Oromia and abstracts water from Awash River.

The River Awash is a trans-regional springing in Oromia and after a long journey reaches to Afar and seeps to the ground near the Ethiopian-Somali/ Djibouti border. Awash River is 1200 km long River basin of 112,696 km2, 4.9 billion m3 and having a potential irrigable land of 134,121 ha (Awulachew, 2007).

Providing efficient physical irrigation structures, putting in place effective water management, establishing dynamic irrigation institution and dynamic relevant operation and management can be taken as the main pillars of effective, efficient, and sustainable agricultural production.

Fentale Irrigation Based Integrated Development Project area is among the most drought prone areas. The present farming level is that of subsistence farming. People are agro-pastorals and in which mixed-cropping system is being practiced. In the absence of any significant extent of irrigation, there are vast lands under natural thorny bushes, shrub cactus-tree vegetation cover, which fit for only some browsing animals with little grass lands for the grazing of cattle. (FIBIDP) (Final study and Design Report February 2011).

The lively hood of the community was based on Pastoral and little rain -fed agriculture and the outputs are too low as the results of scarcity of rainfall in the area. Hence, food shortage becomes common year-to-year problem in the study area.

Therefore, the Oromia Irrigation Development Authority / OIDA decided to intervene in the situation, through the Fentale Irrigation Based Integrated Development Project, that aimed to the improvement of agricultural production, with a view to realize the objective of food self-sufficiency, food security and hence improvement of social facilities.

Irrigation development, which can contribute for food security, employment and agro-industry, but the challenge in attaining such sound irrigation is not easy. The need to increase agricultural productivity and attain food security is nowhere more pressing than in Ethiopia, which has become a typical case of recurring famines and food insecurity, and is a major recipient of foreign food aid (Ersado, 2005).

One of the options to increase agricultural productivity is in irrigation development FIBIDP currently is supplying irrigation water for 4000 ha out of 18000 ha planned. The project has started to irrigate before seven years and it passed nearly eight to ten irrigation seasons at different irrigation blocks based on the completion of farm irrigation water supplying structures and land distribution.

The project is delivering water in two different systems, gravity and pump. In Boset district due to the elevation difference between the main canal and the command area the gravity system is not capable of delivering water, instead Pumps are installed to irrigate 500 ha with two storage ponds and the beneficiaries of these irrigation technology harvested for more than four irrigation seasons. On the other hand more than 15,200 ha of land categorized in different blocks also benefited from irrigation.

1.2. Statement of the Problem

Irrigated agriculture has made a major contribution to the food production and food security throughout the world. Without irrigation, much of the impressive growth in agricultural productivity over the last 50 years could not have been achieved. Nevertheless, it is widely accepted that the overall performance of irrigation and drainage investments has too often been fallen short of the expectations of planners, governments and financing institutions (FAO, 1996).
Ethiopia cannot hope to meet its large food deficit through rain-fed agriculture alone. To mitigate the food insecurity that is prevailing in Ethiopia, different strategies have been suggested by the government. One way for enhancing productivity of the small holding farming is through the promotion of irrigation schemes. The idea is that developing new modern irrigation schemes, rehabilitating the traditional irrigations and wise utilization of surface and ground water are among the points forwarded. As a result, a number of irrigation schemes have been constructed by the federal government, the regional governments and international NGO's with the potential of assuring irrigation.

In Oromia, river diversion schemes have been built or rehabilitated. Non-governmental organizations and communities are also undertaking water resource development activities. Besides development of new schemes, some traditional systems are also being rehabilitated. But, the major focuses of the irrigation development initiatives in the region were on the constructions or engineering aspects. However, issues such as, water use rights and allocation, operation and maintenance, and establishment and strengthening of evaluation of the performance is also should be the most essential part of project management.

Given that, the cost of launching new irrigation investment for food production is high, and that the performance of the existing irrigation systems is below its potential.

Fentale Irrigation Based Integrated Development Project has also the problem of timely completion, planning construction and efficiently performing problem. There is a need for research and capacity building to understand the complex issues of water use and water management, to deal with land management issues to enhance food security, to reduce poverty and speed up national economic development.

In view of the above background problem, knowing the efficiencies and the effectiveness of water use at farmer's level to alleviate the current challenges caused by inefficient operation of irrigation system and poor management of irrigation water that would help to improve the performance of the irrigation system in terms of efficiencies is of paramount importance. Therefore, it is necessary to assess the gains and information that can improve the performance of such irrigation investment in order to achieve incremental production, to create a sense of ownership and consequent commitment to the project performance evaluation and characterization.

1.3. Objective of the Study

The overall objective of the study was to characterize the Fentale Irrigation Based Integrated Development project and to evaluate the value of performance of engineering system under the existing farmers' irrigation practices using selected performance indicators for the betterment of the scheme water management practice and sustainable irrigation agriculture development.

1.3.1. Specific Objectives:

1. To Characterize the Fentale Irrigation Based Integrated Development project
2. To evaluate the technical and economic performance of Fentale Irrigation Based Integrated Development project

1.4. Significance of the Study

Irrigation technology is one means by which agricultural production can be increased to meet the growing demand for food. This implies that irrigation is one of the ranges of technologies available to increase agricultural production and maximize household income to improve rural livelihood. Thus, this study primarily focused on characterizing the scheme, as well as technical and economic performance evaluation of FIBIDP, assessing the determinants of intensity of irrigation water use. The results are expected to be useful for policy makers and different organizations that are involved in the promotion of irrigation development in the region and at national level.

The results of the study could also make its own contribution as base line information for further studies on the economic aspects of irrigation water use. The results of the study on the factors that determine the willingness of the users to maintain keep and manage the scheme elements determinants of irrigation water use decisions, which is vital for the government, policy makers and irrigation users that leads to using irrigation schemes on sustainable basis. In addition, the results of the study would add to the existing stock of knowledge on irrigation that may important for researchers.

1.5. Scope of the Study

The study is aimed at identifying the problems in construction, maintenance, performance and timely completion of such projects and irrigation scheme as well as assessing the intensity of irrigation water use. This study is limited to the Oromia National Regional State, East showa zone. This is mainly because of limited availability of resources to undertake the study at a wider scale. For the same reason, the sample size is limited to few respondents.

Adoption and use of irrigation technology is a process, which takes place over long period of time. In this study, however, only some part of the project will be analyzed which might not be enough to capture the whole variations that would happen through time. Although the study is limited both in sample size and area coverage, the results of the study are expected to be of value in designing appropriate irrigation polices and being well aware in effective performance of irrigation schemes.

1.6. Organizations of the study

The remaining chapters of the study are structured as follows. In chapter two, review of theoretical and empirical literature related to irrigation agriculture is presented. Chapter three and four deal with the methodologies, results and discussion of the study. Finally, chapter five summarizes the main findings of the study and implications.

2. LITERATURE REVIEW

2.1. Importance of Irrigation in Agriculture

Uneven spatial and temporal distribution of rainfall in the country adds to the problems. Irrigation development is key to the sustainable and reliable agricultural development, and thus for the overall economic development of the country. In order to ensure food security at the household level for Ethiopia’s fast growing population, small, medium and large scale irrigation infrastructure needs to be developed. Such development could also generate externally marketable surplus that would earn the much needed foreign exchange and provide required raw material to the local industries.

The principal objective of the irrigation development strategy is to exploit the agricultural production potential of the country to achieve food self sufficiency at the national level, including export earnings, and to satisfy the raw material demand of local industries, but without degrading the fertility and productivity of country’s land and water resources base. More specific objectives of the strategy are to: expand irrigated agriculture, improve irrigation water-use efficiency and thus the agricultural production efficiency, develop irrigation systethatare technically and financially sustainable.(Ethiopian Water sector Strategy)

Main Elements of the Irrigation StrategyDesign appropriate irrigation schemes by taking into account the physical conditions, hydraulic characteristics, irrigation engineering, management capacity of the users, and detailed agronomic and agricultural considerations such as crop water requirements, irrigation methods, integrated pest management and farming practices. Implement measures to secure long-term viability and sustainability of irrigation schemes.

Towards this end, develop complementary infrastructures and share development costs with other sectors, and involve relevant institutions in the planning and development of schemes. Also, enhance the adoption of improved agricultural practices based on detailed agronomic and agricultural studies of crops, soils, farming practices, efficient irrigation methodology, etc that will contribute to improved irrigation systems management.

Of all economic sectors, agriculture is the sector where water scarcity has the greatest relevance. Currently, agriculture accounts for 70 percent of global freshwater withdrawals, and more than 9 percent of its consumptive use. Under the joint pressure of population growth and changes in dietary habits, food consumption is increasing in most regions of the world. It is expected that by 2050 an additional billion tons of cereals and 200 million tons of meat will need to be produced annually to satisfy growing food demand (FAO, 2012).

The global water crisis has drawn worldwide attention to the urgency of achieving a more efficient use of water resources, particularly in agriculture, to increase crop production and achieve world food security. Considering that a major share of the world`s water resource issued in agriculture and that food requirements are increasing while global water resources are limiting irrigated agriculture and therefore, the role of efficient irrigation systems and techniques have recently assumed greater importance in increasing food production (Dabour, 2002). FAO pointed out that, over the past 30 years, the world's total agricultural production doubled, while the expansion of cultivated land was only about 15 percent and all of this growth was occurred in land equipped for irrigation (FAO, 2012).

FAO recently reviewed the current status and role of irrigation in 93 developing countries, and assessed the likely situation of irrigation in 2015 and 2030. The main results of the study, in terms of agricultural production, land under irrigation and agricultural water use are presented. The study shows that fears of a looming crunch between population growth and land availability are unwarranted. According to the same source in the recent past, world demand for agricultural products has slowed, driven mostly by a decreasing rate of population growth and the fairly high levels of food consumption reached in many countries. Future demand growth will slow further. If, at the global level, the production potential exists to cope with increasing demand, developing countries will be more dependent on agricultural imports, and production in poor areas must increase if food security is to improve. The same applies to land and water resources.

The study also forecasts, in the future, 80 percent of increased crop production in developing countries will come from intensification: higher yields, increased multiple cropping and shorter fallow periods. Cropping intensities and yields are systematically higher in irrigated than in rain fed areas. The remaining 20% will come from expansion of agricultural land, mainly in countries showing important potential. To meet future food demands and growing competition for clean water, a more effective use of water in both irrigated and rain fed agriculture will be essential. Options to increase water-use efficiency include harvesting rainfall, reducing irrigation water losses, and adopting cultural practices that increase production per unit of water.

2.2. Overview of Irrigation Development in Ethiopia

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley for the first time. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley (Seleshi *et al*., 2007).

2.3.Current Status of large-Scale Irrigation Schemes in Ethiopia

According to (Seleshi*et al.*, 2010) the current estimates of irrigation schemes of the country cover about 640,000 ha. However, there is some uncertainty about the exact number and location of some schemes, particularly small-scale irrigation and rainwater harvesting (RWH). These irrigation schemes vary widely in size and structure, from micro irrigation (RWH), to river diversion, pumping, and small or large dams, etc. These schemes can be subdivided into: Large-scale irrigation,(LSI) covering more than 3,000 hectares, which is typically commercially or publicly sponsored.

SSI (small scale irrigation) schemes are the responsibility of the MoARD and regions, while MSI and LSI are the responsibility of the MoWR. Seleshi *et al.* (2010) pointed out that it is relatively easy to identify and map LSI and MSI, the information related to SSI is not readily available and data about many RWHs are extremely difficult to capture due to poor information management and availability of data.

The current development has been focusing on the development of small scale irrigation. To address the problem of food security, and to meet the demands of food and fiber requirement, the country has prepared a five year growth and transformation plan to develop additional 1.16 M ha of land, which is an increase of around 280 percent of the currently irrigated land. SSI and RWH will account for about two-thirds of this expansion, as they require lower capital and technical investments, labor is available, they are able to reach fragmented communities and households, and they are possible on small plain areas (Seleshi *et al.*, 2010).

2.4. Irrigation Status in Oromia

Oromia is the largest state in terms of both population and land area in Ethiopia. It covers a total geographical area of about 355,000 square km. The region is characterized by immense geographical diversity consisting of high and rugged contoured mountains dissected by the great East African Rift Valley. Oromia has an estimated total population of 26,553,000, of which 23,030,000 (86.7 percent) of the population are estimated to be rural inhabitants, while 3,523,000 (3.3 percent) are urban (CSA, 2005).

In Oromia, river diversion schemes have been built or rehabilitated. Non-governmental organizations and communities are also undertaking water resource development activities such as water harvesting. Besides development of new schemes, some traditional systems are also being rehabilitated..

One of the major problems related to the sustainable use of irrigation schemes that have been developed by government in many developing countries including Africa is lack of financial resources for covering operational and maintenance costs.

2.5. The Need for Characterization and Performance Evaluation of Irrigation Projects

The major focus of the irrigation development initiatives in the region were on the constructions or engineering aspects. However, issues such as beneficiaries' selection, water use rights and allocation, operation and maintenance, and establishment and strengthening of water users associations are important for sustainable and effective irrigation development

2.5.1 Characterization

2.5.1.1.Soil characterization

On the design document, integrated water shade management plans; both engineering measures and bio measures were recommended. However, on the field visit, no water shade management work was implemented whether to protect the main canal or to protect flood coming in the canal with canal silting materials.

Based on soil depth, slope and salinity/sodicity characteristics a total of soil mapping units (SMU) were identified, excluding the rocky and hilly units. High soil pH, salinity, sodacity and coarser soil texture are the prominent characteristics of the soils restricting the suitability of the soils for various crops (OWWDSE design document).

The crop suitability evaluation indicated that sugar cane, onion, maize, sorghum, alfalfa, cabbage and pepper could be cultivated by irrigation. The soils in the western part of the study area have better potential for irrigation development than the soils in the eastern part.

Photo .2.1. Gully formation on Awash Valley

For the sustained irrigation development, it was recommended that the high soil pH, salinity and sodicity problems in the study area should be reduced by appropriate management practices. Safe disposal of the drainage water and integrated watershed management of the adjacent mountains and hills was very important. The same source showed, the major limitations that downgraded the suitability level of the area to moderate subclass are high pH, salinity and sodicity levels in the study area. This indicates that with high level of management practices the limitations can be corrected, and the suitability and expected crop yield could be increased.

The coarser soil texture and the presence of some amount of calcium carbonate in the soils are favorable for the correction of the stated soil limitations. But, there is no correction measure as per the design related with the improvement of soil PH.

- ❖ **Vegetation control**

We have already stated that aquatic vegetation is liable to proliferate inside a canal. This is due to the availability of large quantities of water, bottom sediment for root growth and, especially with respect to irrigation canals, abundant sunlight and good temperatures, all of which is highly favorable to prolific vegetation growth. The Imperial Aragón Canal, which was constructed two centuries ago (Kenneth, 1988).

- ❖ **Cleaning up sediments**

Solids carried along by the water will nearly always sediment out in the same locations in a canal. These are the solid particles that the water flow is no longer capable of carrying along. A typical location is at inverted siphon pipes. The water, as it leaves the pipe and begins its upward journey through the siphon outlet, is unable to carry the particles with it due to the force of gravity and hence sediment collects at the bottom. The actual problem is not serious as long as the deposits do not grow sufficiently to produce significant head loss. Although the sediment is removed when the canal shows signs of becoming sluggish, the problem will continue, because the replacement of such sediment can occur very quickly. In fact, what is really serious is sedimentation in small watercourses, which then can become blocked. What has to be achieved is that the water always has to possess sufficient tractive force to prevent sedimentation, but, of course, without causing any erosion in the case of an unlined canal. This is not an easy problem to solve and, on many occasions, the only solution is to install settling tanks (Section 11.8), for which it is not always possible to find cleaning outlets. We have already discussed the beneficial effect of regulation reservoirs installed in the canal. Both require periodic cleaning operations.

- **Maintenance and conservation of civil works**

In order to achieve good levels of maintenance and conservation in canals, whatever their purpose, it is essential for the personnel to carry out frequent inspections under the careful supervision of the chief engineer responsible for the canal, so that any emerging problem can be detected at a very early stage of development. However, certain points, due to frequency or importance, require special attention. These are vegetation growth control, the early detection of filtrations, sediment removal and the conservation of metal elements (Kenneth, 1988).

- **Optimum section for an unlined canal**

Any effects of erosion on the lining because the water speed does not usually reach dangerous levels. However, it must be emphasized that in canals with membrane linings, it will be necessary to employ extreme precautions in the case of relatively high water speeds. In the case of unlined canals is very different, with great significance placed on the erosion and sedimentation problems. For this reason, we have explained the methodology for dimensioning a trapezoid section canal, with very careful consideration given to the erosive forces. A better solution would be to construct a canal without a trapezoid section, but instead with an iso-resistant section, one with equal stability against the combination of attractive force and danger of slope sliding, at all points, which is evidently much better than the trapezoid shape with some points that are weaker than others (Kay, 1986).

The performance of any irrigation system is the degree to which it achieves the desired objectives. Hence, evaluations are useful through a number of tools in order to improve the overall management of the system and enhance efficiency. According to Molden *et al*. (1998)

the principal objective of evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. Moreover, performance is assessed for a variety of reasons such as to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; to compare the performance of a system with others or with the same system overtime.

As many farmers are managed irrigation scheme do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993). The evaluation of surface irrigation at field level is an important aspect of both management and design of the system.

2.5.2. Performance Evaluation

Regarding the different approaches of soliciting evaluation data, it can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The other means of collecting the evaluation data is through conducting assessment research. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity (Molden *et al*., 1998). With these indicators the amount of deviation between the actual values against the intended are evaluated.

2.5.2.1. Irrigation efficiency

According to Michael (1997), irrigation water use efficiency is the ratio between the volume used by plants throughout the evapotranspiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application to irrigation plots. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this but scarce resource.

According to Keller, *et al*. (1996), the classical overall irrigation system efficiency (EO) is defined as the volume of water used beneficially (net crop evapotranspiration) divided by the volume of water diverted. Effective efficiency (EE) is defined as the ratio of net crop evapotranspiration divided by the net volume of water delivered to a field. The volume of water that becomes unusable, surface runoff or deep percolation is subtracted from the total volume delivered when calculating the denominator ratio.

Irrigation efficiency has a tremendous impact on agricultural water demands. Understanding how irrigation efficiency fits into estimation of water requirements is essential. Zadalis, *et al*.(1997), considered the effective rainfall in the definition of efficiency. The mean irrigation efficiency for each system is defined by the ratio of the net volume actually used by the crops and the volume released at the head of the main canal, and is given by the equation:

$$E_{E} = \frac{(ETc - Pe)}{Vs}$$

Where:

ETc is the estimated water used by crops,

Pe is the effective rainfall, and

Vs is the volume of water delivered to each network or canal.

The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Once the conveyance and field application efficiency have been determined, the scheme irrigation efficiency (ES) can be calculated, using the following formula (FAO, 1989):

$$E_{S} = \frac{(Ec - Ea)}{100}$$

Where:

ES is scheme irrigation efficiency (%)

Ec is conveyance efficiency (%), and

Ea is field application efficiency (%)

According to (FAO, 1989) a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. It should be kept in mind that the values mentioned above are only indicative values.

The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. Among the factors used to judge the performance of an irrigation system or its management, the most common ones are efficiency and uniformity. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners.

Common performance indicators defined by Kloezen and Garces-Restrepo (1998), based on literature include:

- conveyance efficiency, distribution efficiency, field efficiency, application efficiency and project efficiencies;
- reliability and dependability of water distribution;
- equity or spatial uniformity of water distribution; and
- adequacy and timeliness of irrigation delivery

2.5.2.2 Conveyance efficiency

- The conveyance efficiency (EC) is defined as the ratio between the irrigation water that reaches a farm or a field to that of diverted from the water source and is expressed in percentage (Odhiambo and Kranz, 2011) as:

$$\text{Conveyance efficiency } (E_C) = \frac{V_f}{V_t} * 100$$

- where, Ec = water conveyance efficiency (%)
- Vf= volume of irrigation water that reaches the farm or field
- Vt = volume of irrigation water diverted from the water source
- The conveyance efficiency is the efficiency of water transporting canals or pipes in the field. It is mainly depends on the length of the canals, the soil type, permeability of the canal banks and the condition of the canals. In large irrigation schemes, more water is lost than in small schemes due to a longer canal system. When water is conveyed in pipes, mainly depends on pipe leakage and is usually close to 100 % for new systems.
- According to Brouwer and Prins(1989), the conveyance efficiency for long unlined canals (>2000 m), the conveyance efficiency have been reported as 60, 70, 80% for sand, loam, and clay soil respectively; for medium length unlined canals (200-2000) as 70, 75, 85% for sand, loam and clay soil respectively; and for short canals (<200 m) as 80, 85 and 90% for sand, loam and clay soil respectively. The efficiency of lined canals has been reported in the order of 95% for all canal length.

2.5.2.3. Application efficiency (Ea)

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply the water and to store it in the crop root zone to meet the crop water requirement (Odhiambo and Kranz, 2011). After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency. One very common measure of on farm irrigation efficiency is application efficiency. That asks how much of the water applied to the crop is actually used for crop growth or other beneficial uses. Losses from the field occur as deep percolation (depths greater than required depth) and as field tail water or runoff and reduce the application efficiency.

To compute application efficiency it is necessary to identify at least one of these losses (deep percolation and field tail water or run off) as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, i.e. the amount of under-irrigation in the soil profile must be determined as well as the losses (FAO,1989).

According to Jurriens et al. (2001), the application efficiency is a common yardstick of relative irrigation losses.Losses from the irrigation system via runoff from the end of the field are indicated in the tail water ratio. Runoff losses pose additional threats to irrigation systems and regional water resources. Erosion of the top soil on a field is generally the major problem associated with runoff. The sediments can then obstruct conveyance and control structures downstream, including dams and regulation structures.

Kenneth(1988) indicated that attainable water application efficiencies varied greatly with irrigation system, type and management, and suggested that the attainable application efficiency for surface irrigation were in the order of 80-90%, 70-85% and 60-75% under basin, border and furrow type of system respectively. While FAO(1989) suggested 60 % attainable water application efficiencies for surface irrigation method. Also Norman(1999), said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) was included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable. Lesley (2002) suggested that it could be in the range of 50-80%. In general, according to Michael(1997), water application efficiency decreases as the amount of water applied during each irrigations increases.

Drainage past the root zone is a particularly difficult component to measure and can be estimated by difference, i.e. other components are measured or estimated and the drainage is calculated as follows (Hodgson et al. 1990):

Deep percolation = inputs (irrigation water applied + effective rainfall) - outputs (crop water use + surface runoff + change in moisture)

All these components can then be used to estimate the application efficiency, the uniformity of the application, the adequacy of the application, and the effectiveness of the irrigation in meeting the target application. Reporting the efficiency derived from these values is meaningless without including the water balance used to calculate the preferred measure

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2.5.2.4. Water storage efficiency (Er)

According to Mishra and Ahmed(1990) and (FAO, 1989), the water requirement efficiency, is also commonly referred to as the storage efficiency. The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone. This value is important when either the irrigations tend to leave major portions of the field under- irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs. This parameter is the most directly related to the crop yield since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level.

The adequacy of an irrigation turn expressed in terms of storage efficiency, which is defined by Jurrienset al.(2001) as the ratio between the storage depth and the required depth. The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. In other words,it is defined as a ratio of the volume of water actually stored in the subject region to the volume of water that can be stored (Zerihunet al., 1997). Small irrigations may lead to high application efficiencies, yet the irrigation practice may be poor.

The concept of water storage efficiency is useful in evaluating this problem. Jurrienset al. (2001) express adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tail water the uniformity of the applied water, and the remaining deficit or under-irrigation within the soil profile following irrigation.

2.5.2.5. Distribution uniformity

Distribution uniformity (Du) is a measure of how evenly water is applied during an irrigation event. This uniformity of application can have a considerable effect on crop yield and optimum water application. There are several interpretations in the literature, but a common measure for surface irrigation systems is to divide the average depth infiltrated calculated from the quarter of the field with the lowest infiltrated depths, by the average infiltrated depths. This is called the 'low quarter '.

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a water front will advance at a monotonically decreasing rate until it reaches the end of the field. If it is not dyked, runoff will occur for a time before recession starts following shutoff of inflow. Application uniformity concerns the distribution of water over the actual field. A number of technical sources suggest the Christiansen coefficient as a measure of uniformity. Others argue in favors of an index more in line with the skewed distribution. For example, Merriam and Keller (1978) propose that distribution uniformity be defined as the average infiltrated depth in the low quarter of the field, divided by the average infiltrated depth over the whole field.

The same authors also suggest an 'absolute distribution uniformity', which is the minimum depth divided by the average depth. Thus, the evaluator can choose one that fits his or her perceptions but it should be clear as to which one is being used. To get a complete picture of an irrigation performance you need to know more than just the indicators above, because these are average taken over the entire length of the field. Although different cases might produce the same results for Es and Ea their distribution patterns could differ. One indictor used to represent the pattern of the infiltrated depths along the field length is the distribution uniformity (Kruse, 1978) cited by Jurrienset al.(2001), which is defined as the minimum infiltrated depth (Dmin) divided by the average infiltrated depth (Da), or

$$Du = \frac{D_{min}}{D_a}$$

2.6. Crop Water Requirement

Crops will transpire water at the maximum rate when the soil water is at field capacity. Broner(2003) reported that knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world (Adeniranet al., 2010).

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel, 2004). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha and Henery, 2000).

2.6.1. Reference crop evapotranspiration

To calculate reference crop evapotranspiration, the equation below Allen et al. (1998) as recommended by the FAO has been in use.

$$ETo = \frac{0.408\Delta(Rn + G) + \gamma \, X \, \frac{900}{T+273} U_2 \, (e_{s-} e_a)}{\Delta + \gamma \, (1 + 0.34U_2)}$$

Where, ETo= reference evapotranspiration (mm day-1)

Rn= Net radiation at the crop surface (MJ m-2 day-1)

G = Soil heat flux density (MJ m-2 day-1)

T = Mean daily air temperature at 2m height (oc)

U2 = Wind speed at 2m height (ms-1)

es = Saturation vapour pressure (kPa)

ea =actual vapour pressure (kpa)

(es - ea) = Saturated vapour pressure deficit (kpa)

Δ = slope vapour pressure curve (kPaoc-1)

γ = psychrometric constant (kPaoc-1)

Based on the comparative studies of the reference evapotranspiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the FAO Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration (Smith *et al*., 1991). It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data-short situations The calculation can be done using CROPWAT model.

The use of the modified Penman-Monteith equation in irrigation practice requires empirical coefficients to modify in general to reduce but sometimes to increase the estimates of reference crop evapotranspiration (Stanhill, 2002). The limited availability of the full range of climatic data (particularly data on sunshine, humidity and wind) has often prevented the use of the combination methods and resulted in the use of empirical methods (which require only temperature, pan evaporation rate, or radiation data). This has contributed to the confusing use of different methods and conflicting evapotranspiration values.

To overcome this constraint and to further use of a single method, additional studies have been undertaken to provide recommendations on the using FAO Penman-Monteith method when no humidity, radiation or wind data are available. As a result, procedures are developed to estimate humidity and radiation from maximum/minimum temperature data and to adopt global estimated for wind speed. The availability of worldwide climatic databases further facilitates the adoption of values from nearby stations. Such procedures have proven to perform better than any of the alternative empirical formulas; and will largely improve transparency of calculated evapotranspiration values.

Input data include monthly temperature (maximum and minimum), humidity, sunshine, and wind speed. Crop water requirements (ETc) over the growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on a well established procedures. The updated values of crop coefficients are determined from Allen et al. (1998).

2.6.2. Crop evapotranspiration

Estimation of ETcis essential for computing the soil water balance and irrigation scheduling. ETc is governed by weather and crop condition (Smith, 2000). The specific wetting (irrigation) events are taken into account. Procedures to estimate ETchave been well established by Doorenbos and Pruitt (1977), using a series of recommended crop coefficient values (Kc) to determine crop evapotranspiration (ETc) from reference evapotranspiration (ETo), as follows:

ETc= Kc * ETo

This formula represents the single crop coefficient. Crop evapotranspiration (ETc) refers to evapotranspiration of a disease-free crop, grown in very large fields, not short of water and nutrient. Reference evapotranspiration (ETo) is calculated based on the FAO Penman-Monteith method.

2.7. Water Productivity

Concept of water productivity in agricultural production systems is focused on ‘producing more food with the same water resources’ or ‘producing the same amount of food with less water resources’. Water productivity (WP) or water use efficiency (WUE) mainly refers to the ratio between output derived from water use and the water input (volume or value of water depleted or diverted) (Clement et al., 2011). The output could be biological goods or products such as crop (grain, fodder) or livestock (meat, egg, fish) and can be expressed in terms of yield, nutritional value or economic return. The output could also be an environment services or functions.

Water productivity is the ratio of crop output to water either diverted or consumed, the ratio being expressed in either physical or monetary terms or some combination of the two(Barker . et al., 2003). Irrigation specialists have used the term water use efficiency to describe how effectively water is delivered to crops and to indicate the amount of water wasted. But this concept provides only a partial and sometimes misleading view because it does not indicate the benefits produced, and water lost by irrigation is often gained by other uses (Seckleret al., 2003).

According to Dang et al. (2001), the water productivity is defined in three different ways. The water productivity per unit of evapotranspiration (WPET) is the mass of crop production divided by the total mass of water transpired by the crop and lost from the soil. The water productivity per unit of irrigation (WPI) is the crop production divided by irrigation flow. The water productivity per unit of gross inflow (WPG) is the crop production divided by the rain plus irrigation flow. Water productivity with reference to evapotranspiration WPET takes into accounts only water evaporated or transpired and is therefore focused on plant behavior whereas WPI and WPG include not only ET but also water used in other ways for crop products and water that is wasted.

2.7.1. Physical water productivity

Physical water productivity (WP) in agriculture refers to obtaining more crop production from the same amount of water. It takes account of water with yield which is defined as the ratio between the actual yield achieved and the total water use (TWU) (Pereira et al., 2009a; Yenesew and Ketema, 2009; Araya et al., 2011). However, other researchers defined WP as the ratio between actual marketable yield and actual seasonal crop water evapotranspiration (Kipkoriret al., 2002; Zwart and Bastiaanssen, 2004; Sisayet al., 2011).

$$CWP = \frac{Y_a}{ET_a}$$

Where,

CWP = crop water productivity (Kg/m3)

Ya = the actual marketable crop yield (kg/ha) and

ETa = the actual seasonal crop water consumption (m3/ha).

To maximize crop water-use efficiency, it is necessary both to conserve water and to promote maximal growth. The former requires minimizing losses through runoff, seepage, evaporation and transpiration by weeds. The latter task includes planting high-yielding crops well adapted to the local soil and climate. It also includes optimizing growing conditions by proper timing and performance of planting and harvesting, tillage, fertilization and pest control. In short, raising water-use efficiency requires good farming practices from start to finish (FAO, 1997). Mekonnen(2011) pointed out that to maximize crop water-productivity it is necessary to shift irrigation water management policy from 'maximum irrigation-maximum yield' to 'less irrigation-maximum CWP'

2.7.2. Economic water productivity

Economic productivity is the gross or net present value of the product divided by the value of the water diverted or depleted, which can be defined in terms of its opportunity cost in the highest alternative use (Sadeghiet al., 2010). It gives an indication of how much value is obtained from the use of water. Based on the scale and purpose of the experiment, researchers used different numerator and denominator to express economic water productivity (EWP). Rodrigues and Pereira (2009) defined it as the ratio between the value of actual crop yield and the total water use, in birr/ m3.

$$EWP = \frac{\text{Gross Benefi t(Birr/ha)}}{\text{TWU } (m^3/ha)}$$

Where, EWP = economic water productivity Birr/ m^3, TWU = total water use (m^3)

2.8. Agronomy of Shallot Crop

The shallot (Allium cepa var.ascolonicum) is originated in tropical central or western Asia (Tindall, 1983). The crop has a wide soil and climatic adaptation and is cultivated both under rainfall and irrigated conditions in Ethiopia. It has a very short growing period of only three to four months which allows it to be grown between other crops during short rains in the dry season. Shallots are grown in the mid- and low altitude areas under rain-fed conditions and to some extent under irrigation. In eastern Ethiopia, they are generally cultivated in pure stands and when rain-fed, farmers prefer the drier small rainy season or delayed planting in the main rainy season in order to lower incidence of diseases (Kebede, 2003). The plant is similar to common onion but smaller. The bulbs when planted divides and produces more than two and up to 15 distinct small bulbs (cloves) which remain attached at the bottom seldom, it produces seed. Shallot is a cool season crop adapted to 15 to 20º C. Bulging is favored by high temperature. Larger bulbs were produced with 15 hours photoperiods than a 10 hours photoperiod. Shallot is propagated by using bulbs or segments as planting materials. Dry bulb rows and one large or two small at spacing of 20 cm between bulbs are planted in each spot. Ridge planting is advisable to ensure drainage.The yield of shallot under farmers` condition is very low (6 t/ha) and as high as 25 t/ ha under good management practice (Getachew *et al*., 2009). The wide gap in yield is attributed to lack of improved varieties, poor agronomic practices and soil fertility and diseases (bulb rot and downy mildew) and insect pests (onion thrips), etc in farmers` field (Getachew and Asfaw, 2000).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

Fentale Woreda shares borders with districts within the zone such as Boset, Arsi zone, Western Harerge zone & Afar Region (Awash National Park). It has about 18 rural and 2 urban Kebeles.

3.1.1. Location

The proposed area is located in Oromia Regional state, east Showa zone Fentale and Boset Woreda. Fentale is found at a distance of 200 km Finfine / Addis Ababa and 100 km from Adama town on Asphalt road. Part of the project area located in Boset Woreda (Kawa and Huluko) is 40-45 km. off the asphalt road to east of Metehara town. Generally, both woredas are low land agro-ecological zone characterized by low annual precipitation and high temperature and geographically in the main rift-valley system among 12 districts in east Showa zone.

The dominant command area is situated west of Metehara town and it is bound to the foot slopes of mount Fentale on the north, Lake Beseka on the east, Rift valley escarpment on the west and rocky land (young lava flow) on the south. More precisely it falls in between 80 50' and 90 04' N latitude and 390 41' and 390 52' E longitude. The study has covered gross area of about 27,000 hectares the altitude ranging from 970 to 1020 m above sea level.(OWWDSE Design document)

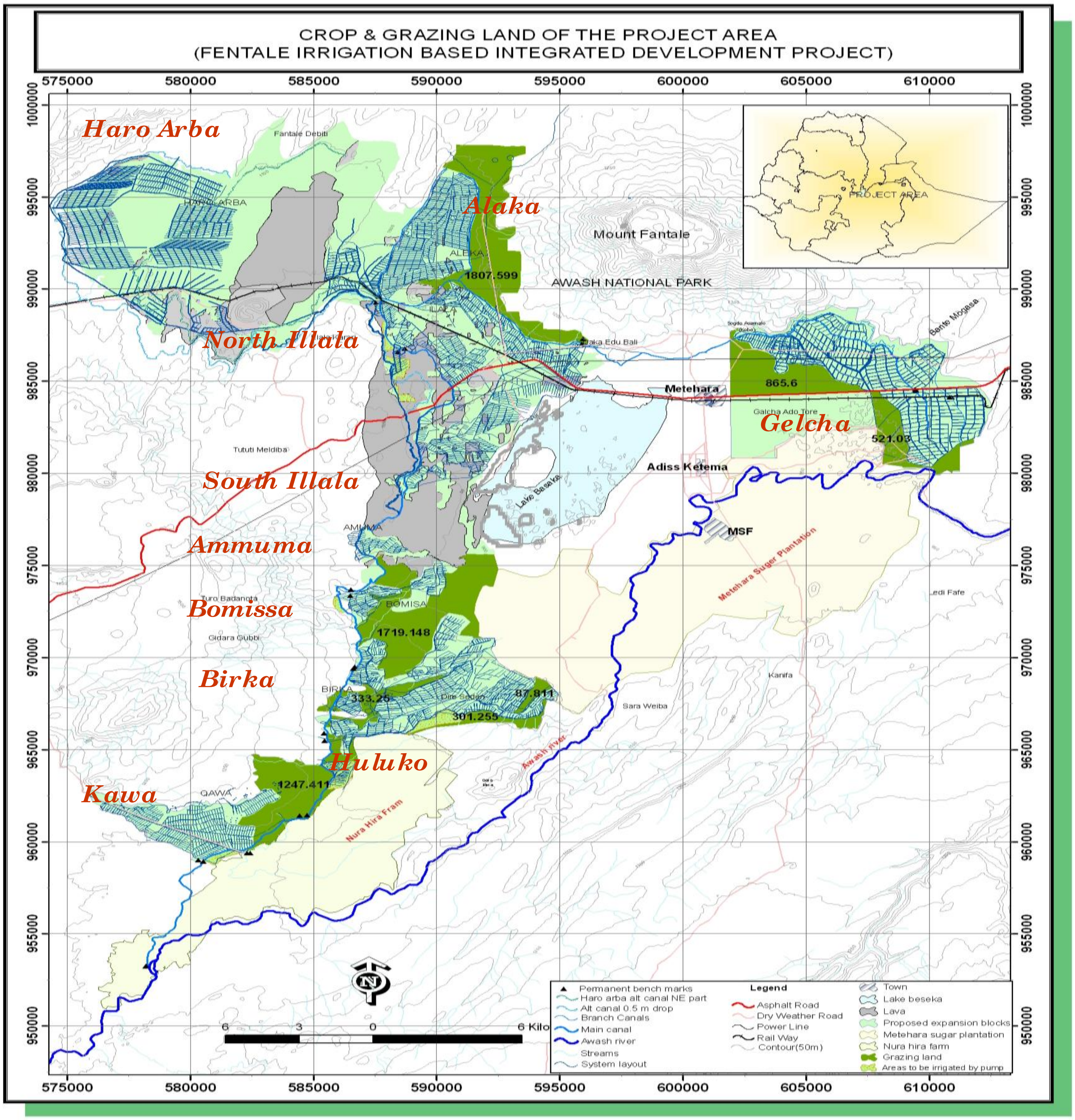


Fig.3.1. Location map of Fentale irrigation Project Area

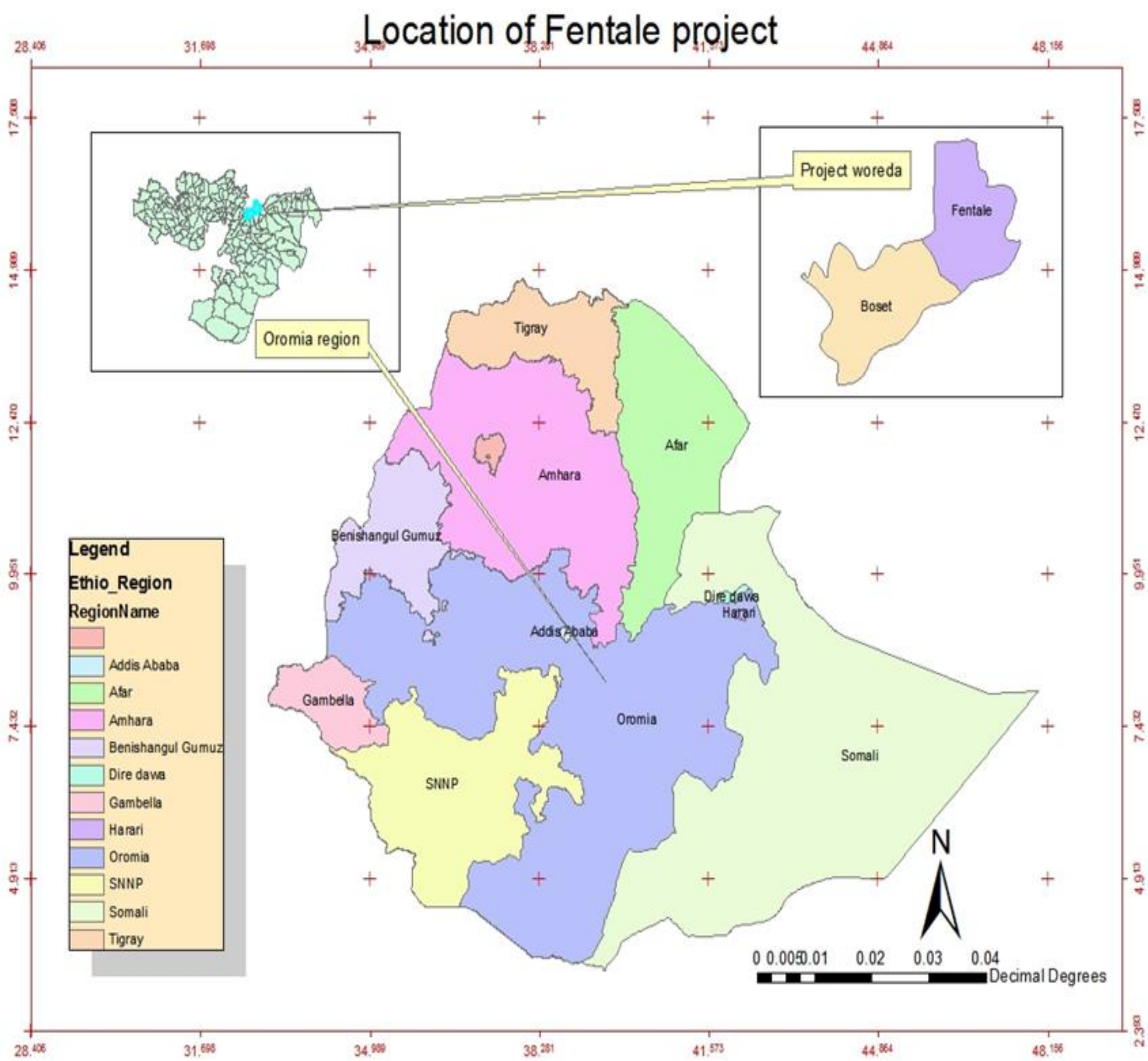
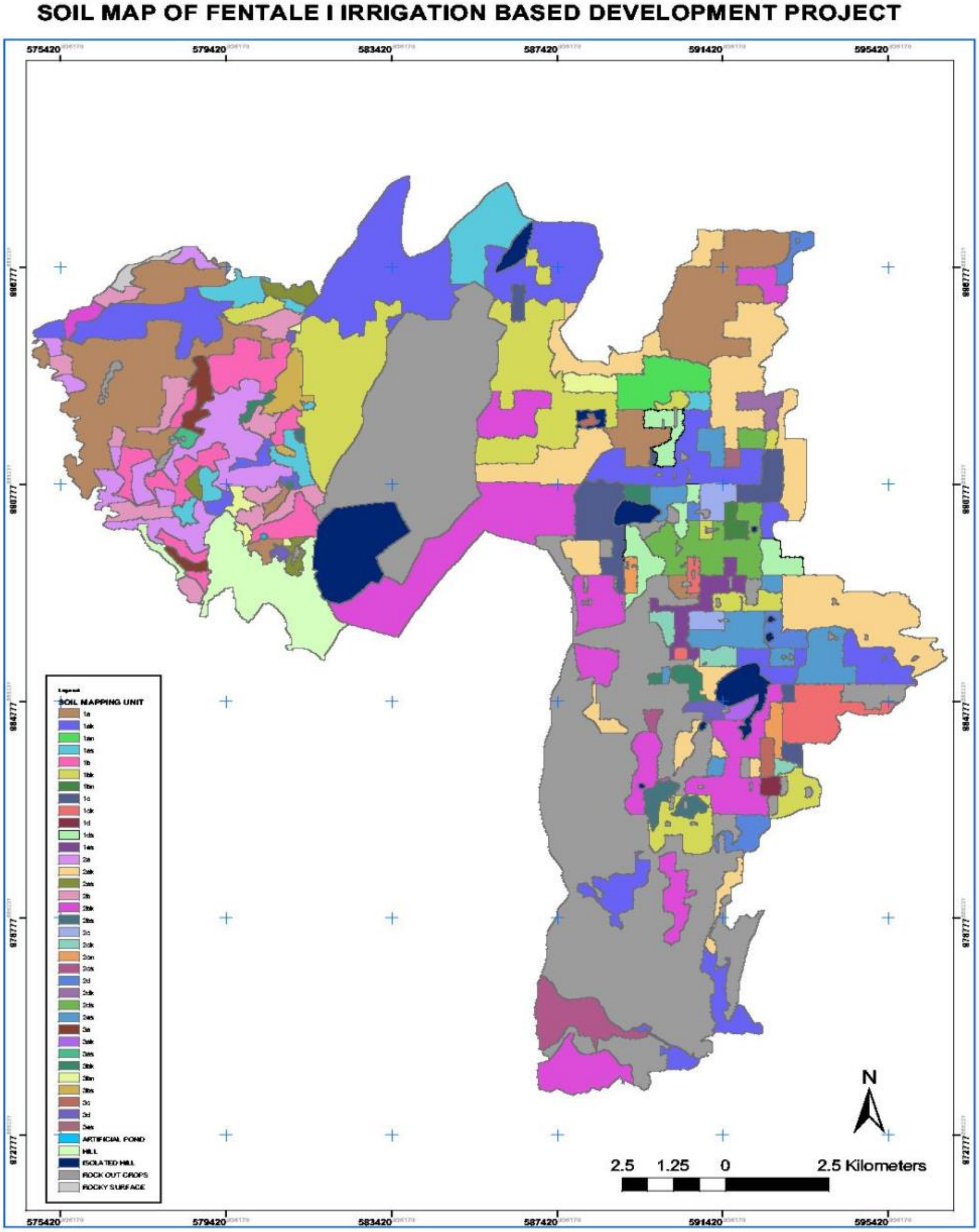


Fig.3.2. Specific Location of the project

3.1.2. Description of Soil Mapping Units

AS per the feasibility report, soil-mapping units have been established based on slope, soil depth and salinity-sod city hazard. Detailed description of these mapping units with respect to soil physical and chemical properties is given below. A total of 35 SMU were identified on the basis of the above three criteria. However, since the third criteria is used to subdivide the mapping units identified by the first two criteria, the description of the SMU is given for the 15 SMU identified on the basis of the first two criteria (slope and soil depth). The distribution of the SMU is presented in Figure 3.3.



FiFigure3. 3. Soil map of the study area

On the basis of soil profile morphology, soil characteristics such as soil depth, color, texture, structure, consistency, presence of acidic material, and soil chemical properties (EC, pH, ESP, etc), the soils of the study area are classified based on the design document.

3.1.2.1. Topography

The flat to very gently sloping topography of the study area makes it suitable for irrigation, drainage and mechanization. Some gently sloping (4-5% slope) areas at the foot of hills and mountains are not suitable for surface irrigation because they are not suitable for leveling due to the very shallow soil depth. They can, however, be used as infrastructure placement or for pasture development by pressurized irrigation systems.

3.1.2.2. Vegetation

The area is characterized by open to denser shrub and bushes which implies that it requires some clearing activities. As most of the vegetation is of the acacia species, leaving some of the stands for shading against the blazing sun heat, as wind break and also for their nitrogen fixing ability is beneficial.

3.1.2.3. Effective Soil Depth

The dominant part of the study area (15,032 ha or 89.9% of the net area) has soil depth greater than 50 cm and of which 13,741 ha of land has soil depth greater than 100 cm. This indicates that soil depth is not a critical limitation for root development and soil moisture storage except for some perennial crops that require very deep profiles. Even the areas with shallow soils appear to be utilized given the very soft and porous nature of the under lying bedrock.

3.1.2.4. Land use

The selected command area of the project spreads over two weredas of Eastern Showa Zone of Oromia Administrative Region. Major project command area falls under Fentale Wereda about 1220 masl. This includes 13 % Arable land, 5.1% cultivated land, 6.9 % bush land, 21.2 % grazing land, 2.8% water bodies and 10.3% unused rocky lands.

The land use data of the Fentale and Bosset district indicates that a very insignificant proportion of the arable land is under cultivation, amounting to 7.8% of the total cultivable land and /or 13 % of the total land area of the district. The main cultivated land is found in the highland where 20 % of the district's rural population resides.

Area and production wise, the most dominant crops are onion, maize, tomato, and pepper, both as a cash crop and staple food for most of the people, both in the district & the project area. From the design document (OWWDSE).

3.1.2.5. Accessibility

The Addis Ababa – Harar asphalt road, which passes through the project area and through the nearest major town, Metehara, provides the main access to the project area. The project area is also accessed by the Addis Ababa to Djibouti railway line. The all-weather road to Sabober hill in the northeast of the project area and a rough road to Berehet in the northwest of the project area provide additional access to the interiors of the project area. Both roads branch out from the main asphalt road at a point very near to the intersection of the asphalt road and railway line, within the project area. Owing to the flat topography and scattered trees, almost all parts of the project area are accessible.

The project area covers Kawa and Huluko from Boset district; and Gidara, Turo Bedenota and Tututi kebeles from Fentale district. The diversion site on Awash River and the Kawa command area can be accessed via Metehara Sugar Factory (MSF) 25 km on all-weather road and 5 km dry weather access road.

3.1.2.6. Climate

The mean monthly minimum and maximum temperature in the project area varies from 10^0C to 38.3^0C respectively. The mean minimum temperature is recorded in December and the maximum is recorded in May. May and June are the hottest months of the year in the project area. Annual rainfall in the project area is about 500mm. Mean monthly rainfall varies from 4.8 mm to 124 mm. The highest rainfall occurs in July and August; while the lowest rainfall occurs in December. The

The methodology used to determine climatic characteristics in the project area is by analyzing the nearby meteorological stations. Meteorological data for all the observed climatic elements computed using short recent available records from Nura Hera and Metahara stations.

Mean annual rainfall	= 508 mm
Minimum annual temperature	= 10 o C
Maximum annual temperature	= 38.3 o C
Mean annual temperature	= 24 0c
Average wind speed	= 9 km/h

3.2. Characterization of the Project

Characterization of the scheme was done by looking into the secondary information from design documents, field observation and canal measurements. Main and branch canals were described in terms of their discharge, canal dimensions, and length of flow and functionality of the scheme elements as well as analysis of number of civil works completed as per the design or not.

Characterization of Fentale Irrigation Based Integrated Development Project is mostly resource characterization such as water and soil resources. The water distribution and management system and the existing conditions of constructed structures were also assessed mostly depending on the main canal. Because, the project is huge and very complex takes time to take the whole inventory to characterize the entire project.

3.2.1.Scheme Characterization

- **Overtopping**

Water in a canal may rise unexpectedly due to several reasons, the incoming flow through the canal off take may be much greater than the canal capacity; obstacles such as stones, blocks or plant growth in the canal may dam up the water outlets from a canal may be closed which should be open; rain or other water may be draining into the irrigation canal; or farmers may make temporary weirs to raise the water level.

If no action is taken, the water level can reach the top of the canal banks and overtop. Overtopping causes erosion of the canal banks and may lead to serious breaches. It can be avoided by improving the operation of the system. Discharges should be limited and gates should only be closed and opened according to the planned schedule. To prevent overtopping, which can happen even in the best irrigation systems,

- **Estimating The Discharge**

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others, and could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge in the canal. The discharge in a canal can be measured with or without a discharge measurement structure.

method described here is called the _floating method_. This method is a quick and cheap way to estimate discharge in a canal. However, this method is not very accurate and errors of at least 10% can be expected. The method consists of estimating the average flow velocity (V), and measuring the area of the cross-section, called the 'wetted cross-section' (A). The discharge (Q) can be calculated by the following formula:

$Q = V A$

Where:

Q is the Discharge in m3/s;

V is the Average Flow Velocity in m/s;

A is the area in m2 of the Wetted Cross-section.

To estimate the average flow velocity, the flow velocity of the water at the surface , the surface velocity, Vs , is first determined. The surface velocity is determined by measuring the time it takes for a floating object, such as a stick, a bottle or a coconut, to travel through a previously measured distance of, say, 10 or 20 metres along the canal. The floating object should be placed in the centre of a canal and the time measurement should be repeated several times to avoid mistakes. The stretch of canal used for measurement should be straight and uniform, in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation.

To compute the surface velocity, Vs, the selected length, L, is divided by the travel time, t:

$$V_s = L / t$$

Where:

Vs is the Surface Velocity in meters per second (m/s);

L is the distance in meters between points A and B; and

t is the Travel time in seconds between point A and B.

The surface velocity must be reduced in order to obtain the average velocity, because surface water flows faster than subsurface water. For most irrigation canals this reduction factor is about 0.75. The average velocity is therefore found from:

$$V = 0.75\ V_s$$

Where:

V is the Average Flow Velocity in m/s;

0.75 is a constant, the Reduction Factor; and

Vs is the surface velocity in m/s found from the previous calculation.

Summary of infrastructure condition (from asset survey) Scheme/system level Percentage of structures defective ,Percentage of structures requiring maintenance .Percentage of structures requiring improvement and Percentage of canal length defective and so on.

Additionally, some sort of interviews had been made among the farmer of informal groups;

Farmers' views on responsibility for canal maintenance, the responsible for the maintenance whether OIDA or farmers themselves (WUA)

Farmers reporting a contribution to maintenance, Farmers' perceptions of water supply and system operation Capacity of farmers to carry out repairs/maintenance

a) Flow Measurement

To determine the amount of water applied by the irrigators to the field, during an irrigation event, three inches Parshall flumes were installed at the entrance of test plot. Frequent readings were taken when the farmers irrigate the test plot. Irrigation was continuing until the farmers' thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test plot, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test plot being irrigated. The discharge was computed using equation.

Then, the discharge was calculated using the following equations (Walker and Skoerboe, 1987):

$$Q_f = C_f * W * h_u^n f = 0.1765H^{1.547} \text{------------------------------}(3.1.)$$

where:

Q_f is discharge for free flow condition;

W is throat width;

h_u is upstream heads of parshall flume;

C_f is free flow coefficient and

n_f is exponents for free condition. And the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

The amount of depth of water per furrow was computed as follows:

$$D = \frac{Qav\ Tapp}{100A} \text{------------------------------}(3.2.)$$

A = W*L (m2)

where: D= depth of water applied (cm),

A=area over which water is applied (m2),

L = furrow length (meters)

W = furrow width (meters)

Tapp = application time (sec),

Qav =average discharge rate (lit/sec).

To measure the cross section of the furrow, the width of the furrow was determined by selecting three furrows per test plot. The width of each furrow was measured at three points per furrow (top, middle and end) dividing into seven equal segments, and then the average width was calculated. The depths of each segment of the furrow were measured. The area of each segment is the product of the width of segment and its average depth. The areas of the segments are summed to determine the total cross sectional area.

b) Farrow evaluation through Advance and Recession Time Measurements .

In order to measure the behavior of advance and recession curves, furrows on test plots were identified. Wooden posts were placed uniformly along the flow direction at five meters interval. The time it takes for the water front to reach wooden post (advance time) and the time it takes for the water to recede at each wooden post (recession time) was taken and recorded. The opportunity time (the difference between the advance and recession time) at each of the wooden posts was calculated.

c) Primary and Secondary Data Collection

The study was conducted during the dry season when the crops being cultivated under irrigation. The study work was started in the month of November 2013 and continued until March 30 2014. During the study period, regular visits and observations were made to assess the method of water applications and practices related to water management at the study sites. Data collected were including primary and secondary data’s which would help to achieve the study objectives.

d) Field Layout, Crop Selection and Experimentation

In order to evaluate the irrigation water use efficiency of farmers at field level and to compare each other in the scheme, nine farmers' fields were selected three each from the head, middle and tail end water users of the irrigation scheme with respect to water resource. The criteria for selection of a plot were location (head, middle, and tail), their similarity with water management practices, crop grown and willingness of the farmers to collaborate. A total of nine red onion growers' farmers were selected. The reason for the selection of Onion was that it is the dominant and representative crop in which most farms are covered with it because of its production potential and good market in the area.

Figure 3.4 depicts the layout of nine selected fields, grown with onion crops. The selected fields represent from head, middle and tail of the irrigation command area in reference to the water resource.

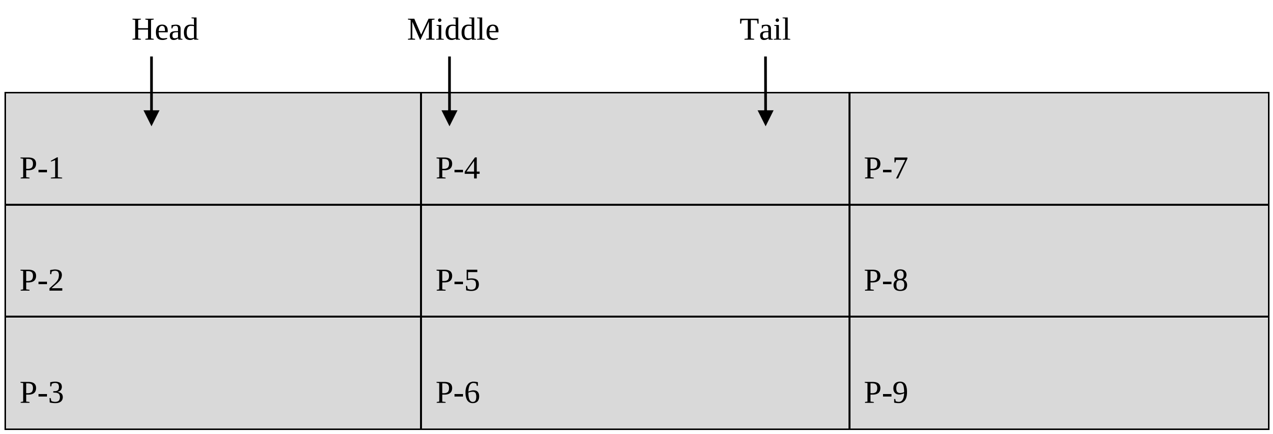


Figure.3.4. Layout of nine-selected farmer's fields
P= Plot

For the present study, Onion was grown in the study area during the first growing season of the year 2013/14. Land preparation was carried out using local plough and after the completion of land preparation the bulb of the onion was planted on the ridges prepared for the intended use. Weeding and insect control were managed by using both cultural practices and herbicides. Fertilizer was not used in all farmers plot.

3.3. Performance evaluation

Performance evaluation was carried out using different resource characterization and efficiency indices. And the results are presented and discussed

3.3.1. Technical performance evaluation

The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. Among the factors used to judge the performance of an irrigation system or its management, the most common ones are efficiency and uniformity. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners.

Common performance indicators defined by Kloezen and Garces-Restrepo (1998), based on literature include, conveyance, efficiency, application efficiency, and storage efficiency.

a) Water conveyance efficiency (Ec)

This is the loss, which occurred through the conveyance systems from the diversion point to the field where the water is to be used. Notably, it is the ratio between water received at the inlet to the field and the amount of water diverted from the source and computed as:

$$Ec = \frac{Wf}{Wd} \times 100 \quad \text{--(3.3\}}$$

where: Ec = water conveyance efficiency (%)

Wf= amount of water delivered to the farm

Wd = amount of water Pumped/diverted from the source

The conveyance efficiency was measured on the main canal by measuring discharges at two different points. The discharges were calculated from the velocities of the water flowing in the main canal using floating materials. The method of discharge measurement is called **floating** method as floating materials being used for velocity measurement. The discharge measurement was conducted in the upper position of the main canal. Floating material was put on the upper end of the canal section and the time it took to reach the marked section of the same canal was registered. This test was replicated five times and the average time it took was taken to calculate the discharges. The cross sectional area of the canal was also estimated by measuring the average depth and width of the same canal section. The average velocity and the rate of flow (discharge) were calculated by dividing the distance with the average time, and by multiplying the cross sectional area with the average flow velocity, respectively. Then continuity equation ($Q = A \times V$) was used, where, Q is the discharge (m^3/sec), A, the cross sectional area of the canal (m^2) and V, the average flow velocity (m/sec).

The second measurement was taken at a fixed distance above the downstream end of the main canal. The same procedure was followed to that of the upper parts of the canal to estimate the discharge at the outlet (the downstream end) so that the amount of conveyance loss was known and the conveyance efficiency was determined. The measurements for both positions were taken twice.

b) Application efficiency estimation

The evaluation of the application efficiency was made on nine selected farmers' fields of irrigation scheme. Water applied to the field was measured by installing 3 inch partial flumes at entrance of selected farmer's field when fields were being irrigated. Before proceeding to the measurement, it was located in straight section of flow. The flow rate was obtained by taking consecutive measurements of water depth, because it has been established that depth varies proportionally with flow. To determine the amount of water applied to the field, water depth passing through the flume to the field and its respective time intervals were recorded with the size of the field being irrigated. Since it is free flow, only upstream measurement point was used. The measurement point was located within the 2/3 portion of the converging section from the beginning of the throat section.

Then, the discharge was calculated using the following equations (Walker and Skoerboe, 1987):

$$Q_f = C_f * W * h_u^{n_f} = 0.1765H^{1.547} \text{ -------------------------(3.4)}$$

Where :

Q_f is discharge for free flow condition

W is throat width

h_u is upstream heads of partial flume

C_f is free flow coefficient and

n_f is exponents for free condition. And the depth of water applied was computed from discharge, cut-off time and area irrigated.

The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

The application efficiency of each field was calculated using equation (FAO, 1989; Michel 2008):

$$E_a = \frac{w_s}{W_f} * 100 \text{ ---(3.5)}$$

Where:

E_a = the application efficiency (%)

W_s = water stored in the root zone (mm)

W_f = Water applied to the field (mm).

The depth of water stored in the root zone of selected field was determined from the soil moisture content before and two days after irrigation by gravimetric method. The depth of water applied to the field was estimated by dividing the average total amount of water applied to the field by the area irrigated. The depth of water retained in root zone was calculated using equation (Michel, 2008)

$$\mathbf{d=} \sum_{i=1}^{n} \frac{(Mafi - Mbi)}{100} * Ai * Di \text{ -- } \mathbf{(3.6.)}$$

Where:

d = depth of water retained into root zone of the soil (cm),

M_{afi} and M_{bi} = moisture contents in the i^{th} layer of the soil after and before irrigation (% weight basis),

A_i = bulk density of the soil in the i^{th} layer,

D_i = depth of the soil i^{th} soil layer within the root zone (cm) an

n = number of layers in the root zone.

c) Storage Efficiency Estimation

Storage efficiency was measured using equation (3.7) as recommended by (Allen et al., 1998 and Michel, 2008):

$$E_r = \frac{w_s}{W_n} * 100 \quad \text{---(3.7)}$$

where, Er = storage efficiency (%),

Ws = water stored in root zone during irrigation (mm),

Wn = water needed in root zone prior to irrigation (mm).

The depth of water retained in the soil compartments of the root zone was computed by equation (3.6) and the water needed in the root zone prior to irrigation is estimated by the equation(3.8) given by (Allen et al,; 1998):

$$Wn = \sum_{i=0}^{n} \frac{(\theta FC - \theta BI)}{100} i * Di \quad \text{---(3.8)}$$

where,

Wn= the depth ofwater needed in the root zone prior to irrigation (mm),

θFC and θBI= soil moisture content at field capacity and moisture content of the soil before irrigation in volume percent, respectively and

Di= the depth of soil profile in root zone (mm).

d) Distribution uniformity Estimation

Distribution uniformity was measured using the distribution uniformity index as proposed by James (1988):

$$Du = \frac{Z\min}{Zav} * 100 \quad \text{---(3.9)}$$

where, DU = distribution uniformity coefficient, in %

Zmin = the minimum depth infiltrated at the ith point, in mm

Zav = the mean depth infiltrated in mm and computed as

$$\mathbf{Zav} = \frac{\sum_{i=1}^{n} Zi}{N} \quad \text{---(3.10)}$$

N = Number of points where samples were taken

FAO (1992) suggested that the average distribution efficiency DU of 65% as sufficient and DU of 30% as poor.

e) Christiansen uniformity coefficient (CUC)

The uniformity of application was evaluated using Christiansen uniformity coefficient (Jurriens et al., 2001). This is given as:

$$Cu = 100\left(1 - \frac{\sum_{i=1}^{n}|d|}{n\overline{X}}\right); \qquad d = Xi - \bar{X} (3.17)$$

d = Xi - j8 ---(3.11) where, Cu = Christianson uniformity coefficient (%)

d = deviation of observation from the mean (cm)

n = number of observations

$\bar{X}$ = average depth infiltrated (cm)

Xi = depth of infiltrated at observation point i (cm)

f) Determination of deep percolation ratio (DPR)

Since the furrows are closed end, runoff ratio is neglected. The loss of water through drainage beyond the root zone is reflected only in the deep percolation ratio that expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field. Also the evaporation from the soil is marginal and can be neglected because it is only a short period after irrigation. Therefore, deep percolation ratio was calculated for selected nine test plots as:

$$DPR = \frac{\text{Volume of deep percolation in } M^3}{\text{v0lume of water applied to the field}} \quad \text{---(3.12)}$$

3.3.2. Economic performance evaluation

An economic efficiency analysis is a systematic way to compare yield which would be produced with the total cost for the production. Two principal value measurement parameters were used in this analysis. To determine the total net contribution (net benefits) of a project to farmers, the net present worth (NPW) was used to provide a systematic ranking of alternatives and it was computed as:

$$NPW = \sum[(Bt - Ct)/(1 + r)^t] \quad \text{--- (3.13)}$$

Where:

Bt and Ct = benefit and cost in a year respectively, and

r=social discount rate.

To compare the benefits to costs, the B/c ratio formula was used as:

$$\text{B/C ratio} = \sum[Bt/(1+r)^t] / \sum[Ct/(1+r)^t] \quad \text{------(3.14)}$$

If B/C ratio is more than 1, the present value of benefit is greater than the present value of costs and project is economically efficient use of resources, assuming that there is no lower-cost means for achieving the benefits.

3.3.2.1. Crop Water Requirement

Crops will transpire water at the maximum rate when the soil water is at field capacity. Broner (2003) reported that knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world (Adeniran *et al*., 2010).

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel, 2004). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha and Henery, 2000).

3.3.2.2. Reference crop evapotranspiration

To calculate reference crop evapotranspiration, the equation below Allen *et al*. (1998) as recommended by the FAO has been in use.

$$ETo = \frac{0.408\Delta(Rn + G) + \gamma \, X \, \frac{900}{T+273} U_2 \,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34U_2)} \quad \text{------(3.15)}$$

Where, ETo = reference evapotranspiration (mm day^{-1})

Rn = Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil heat flux density (MJ m^{-2} day^{-1})

T = Mean daily air temperature at 2m height (^{o}c)

U_2 = Wind speed at 2m height (ms^{-1})

e_s = Saturation vapour pressure (kPa)

e_a =actual vapour pressure (kpa)

(e_s - e_a) = Saturated vapour pressure deficit (kpa)

Δ = slope vapour pressure curve (kPa $^{o}c^{-1}$)

γ = psychrometric constant (kPa $^{o}c^{-1}$)

Based on the comparative studies of the reference evapotranspiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the FAO Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration (Smith et al., 1991). It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data-short situations The calculation can be done using CROPWAT model.

The use of the modified Penman-Monteith equation in irrigation practice requires empirical coefficients to modify in general to reduce but sometimes to increase the estimates of reference crop evapotranspiration (Stanhill, 2002). The limited availability of the full range of climatic data (particularly data on sunshine, humidity and wind) has often prevented the use of the combination methods and resulted in the use of empirical methods (which require only temperature, pan evaporation rate, or radiation data). This has contributed to the confusing use of different methods and conflicting evapotranspiration values.

Input data include monthly temperature (maximum and minimum), humidity, sunshine, and wind speed. Crop water requirements (ETc) over the growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on a well established procedures. The updated values of crop coefficients are determined from Allen et al. (1998).

3.3.2.3. Crop evapotranspiration

Estimation of ETc is essential for computing the soil water balance and irrigation scheduling. ETc is governed by weather and crop condition (Smith, 2000). The specific wetting (irrigation) events are taken into account. Procedures to estimate ETc have been well established by Doorenbos and Pruitt (1977), using a series of recommended crop coefficient values (Kc) to determine crop evapotranspiration (ETc) from reference evapotranspiration (ETo), as follows:

ETc = Kc * ETo

(ETo) is calculated based on the FAO Penman-Monteith method.

3.3.2.4. Yield Data Collection

To assess the overall impact of water distribution and performance parameters on yield, the yield of shallot was collected separately from head, middle and tail end plots. Water use efficiency was then calculated. Shallot was harvested by hand from the three ridges of all plots. The yield of the shallot was collected from three ridges by sampling from each selected plots. This was done dividing the ridges into three equal parts along its length. Then yield was collected from each plot in the fields and weighed. The total yield obtained from the test plot was also measured.

3.3.2.5. Estimation of Water Productivity

To compare the relative water productivity of the farmer`s field at three locations (head, middle and tail), yield of the Onion was collected from each of the nine selected fields. Then the collected yield from each field was weighed. After determining the amount of water applied and estimating amount of water consumed by crop through process of evapotranspiration in a season, the physical Water productivity (CWP) was computed as (Zwart and Bastiaanssen, 2004) by using the following equations

$$CWP\ (kg/m3) = \frac{\text{Total bulbs produced (Kg/ha)}}{ETc\ (m^3/ha)} \qquad \text{---(3.15)}$$

$$\frac{\text{Yield (Kg)}}{\text{Water diverted to the field } (m^3)}$$

Water productivity per unit of water applied (kg/m3) =

---(3.16)

Where; CWP is physical water productivity

The local market price at Metahara during the time of harvest was used to evaluate water productivity on monitory units. Economic water productivity (EWPETc) was determined by dividing the gross benefit to volume of water consumed.

$$EWP\ (Birr/\ m^3) = \frac{\text{Gross benefit (Birr/ha)}}{ETc\ (m^3/ha)} \quad \text{--(3.17)}$$

4. RESULTS AND DISCUSSIONS

4.1. Characterization of the Project

Characterization of the scheme was done by looking into the secondary information from design documents, field observation giving more attention for the main canal, as the completed work was the main canal and it was very difficult to characterize the entire work of the project, because it was very huge and vast.

Main canal was described in terms of its discharge, canal dimensions, and length of flow and functionality of the scheme elements. The soil infiltration rate characteristics, the furrow geometry and slopes, were determined.

Table 4.1 Summary of main canal condition (from asset survey)

Scheme	Percentage of structures defective	Percentage of structures requiring maintenance	Percentage of structures requiring improvement	Percentage of canal length defective	Remark
Main canal	15	40	30	60	

4.1.1. Source of water

flow of Awash River

Observed mean monthly flow data of Koka Dam inflows

Maximum flow of September is 184.6 Mm3

Low flow in February is 77.3 Mm3

Two meteorological observation stations are located in and around the project area. The meteorological data recorded at these stations are obtained from the National Meteorological Services Agency (NMSA). The Metahara and Nura Hera meteorological stations are Class I stations that include observations of rainfall, temperature, relative humidity, sunshine duration and wind speed. The longest record that covers 10 years of data is available at these station which are located within close vicinity or within the project command area and the design document was depended on this hydrological data the design discharge was the smallest which is 77.3Mm3.as described in (Table.4.1).

Table 4.1. Observed mean monthly flow data of Koka Dam out flows

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Flow(Mm3)	87.2	77.3	86.0	83.2	89.9	92.1	97.5	171.7	184.6	115.8	77.	91.4	1266.8

S.No	Description of the Command Area	Command Area (ha)		Irrigation System	Remark
		Gross	Net		

4.1.2. The Command Area

The Command areas of the project are scattered along the main canal and these are divided as south and north blocks. The areas that establish under south block are Kawa, Huluko,Birka,Dreseden, Bomisa, Ammuma, and South Illala. Similarly under North block are North Illala, Alaka, Gelcha, and Haroarba. Consequently, the areas that mentioned on the first block are found between headwork and asphalt Road/ Highway Djibouti to Addis Ababa. Therefore, in all Commanded areas over which the irrigation water through whole canal system can flow by gravity. As observed on the field the project is not functioning as the potential it had discribed on (table 4.2.) Because, the two branch canals and their accessory structures were not completed. The main canal is not exerting the whole designed discharge because branch canals were not completed and, the whole designed command area was not under cultivation.

Table 4.2: Size of Command areas Designed

1	Kawa	1000	874	Pumped/Gravity	
2	Huluko	100	84	Gravity	
3	Birkadreseden	2300	2005	Gravity	
4	Bomisa	187	163	Gravity	
5	Ammuma/Bedenota	202	176	Gravity	
6	South Illala	1112	967	Gravity	
7	North Ilala	1775	984	Gravity	
8	Alaka	1130	983	Gravity	
9	Gelcha	3450	3000	Gravity	
10	Haro arba	6900	6000	Gravity	
11	Areas Deve. By Pump	500	500	Pumped/Gravity	At different reach
Total		**18656**	**13736**		

As shown on (table 4.3.) even the actual command area implemented from the designed was only around 60%. Because, the construction work of the project was not completed on its schedule. According to the site supervisor report, the main problem was shortage of budget and not timely allocation of budget from the client (OIDA).

Table 4.3: Net Command areas Implemented

S.N.	Command area Blocks	Net area (Hectare)	Type of Irrigation system	Remark
1	Qawa	874	Pump irrigation (with two pump station to lift irrigation water	All Irrigation system completed
2	Huluka	84	Gravity pipe system	All Irrigation system completed
3	Brika-Direseden	2005	Gravity pipe system	All Irrigation system completed
4	Bomissa	163	Gravity pipe system	All Irrigation system completed
5	Ammuma (bedonea)	176	Gravity pipe system	All Irrigation system completed
6	Ilala South	967	Gravity pipe system	Completed for 69 ha
7	Ilala North	984	Gravity pipe system	Completed for 412ha
8	Alaka	983	Gravity pipe system	All irrigation system completed
9	Gelcha/ Block	3000	Gravity pipe system	Under construction
10	Haro- Arba	6000	Gravity pipe system	Design
11	Areas Developed By pump.	500	Pumped/Gravity	500 irrigated on different reach
Total		**13,736**		**5276**

4.1.3. Components of the FIBIDP

The most general frame works of the project are as follows:

- Diversion weir and appurtenant works
- Head Regulator for the main canal
- A network of canal system comprising of main, branch and field channels,
- Necessary structures e.g. head and cross regulators of the off taking channels, drop structures, crossing structures, bridges, night storages reservoirs etc.
- A network of drainage system via field drains tertiary drain, collector drain and intercepting drain for drainage of surplus water as well as rainwater.

Diversion weir of Fentale Irrigation based development project is located at Awash River at about 4 km upstream of Bole Bridge near Nuraera State Farm camp No.3 to divert river water into the main canal and an intake structure/head regulator to regulate the diverted flow into the canal. The weir site is located at about 50 km Southwest of Metehara town.

- the wire site is selected at the right side of the canal which is near and accessible for the most command area.
- Intake structures at head work of the main canal was not functioning properly because of lack of maintenance and lack of handling.
- This problem was leading the head work to unnecessary silt trapping around the head work
- The remaining structures on head work were made as per the design
- the adopted design discharge was the smallest which is preferable.

Photo.4.1. Diversion weir Head Regulator

4.1.3.1. Components of Head Works

A Head Regulator structure is provided to facilitate the diversion and regulation of water from the river into the main canal. The river water thus diverted into the canal system is utilized to meet the water demand for irrigation as well as for other needs like domestic needs of population settled in and around the command area and/ or for the needs of livestock in the area.

The essential components of head works are:

Weir 128m length

Design discharge 492m3/sec

Under sluices 112m3/sec

Canal head regulator 18m3/sec

- There were four under sluice gates one of them was not functioning.
- Even the functioning three were also were not under utilization of silt excluding
- There was no trash-rack designed or implemented. as a result there was a deposited of high amount of debris

4.1.3.2. Conveyance Systems and water control structures

- **Main Canal**

The Main Canal is divided in to three reaches. The first reach covers 18 km starting from diversion weir with conveyance capacity of 18m3/sec. The second reach covers about 14 km starting from chain age of 18+000 to 32+000, which has fixed discharge capacity of conveying about 17m3/sec. The third reach covers about 11 km and has relatively gentle slope. Within 43 km stretch, starting from the diversion weir up to the Addis Ababa – Harar asphalt road, the canal bed level has an elevation difference of more than 120m. After crossing the road, the canal extends foe 6.3 km. And the total length of the canal is about 49.3km. For the purpose of canal capacity, the canal up to Asphalt road has been divided in to four reaches:

  - From the head regulator to about 17.525 Km in Gidara PA
  - From 17.525 Km to 26.9 km at Bomisa
  - From 26.9 km to 42.7 km Asphalt Road at Ilala
  - From 42.7 km to 49.3 km up to division box to Alaka and Gelcha command areas.

- During field survey breaking of main canals and illegal water abstraction of irrigation water using water pump even out of irrigation scheme was observed.
- The canal as shown on (photo 4.2) is poorly lined with concrete it is also a little part and it started to be damaged

Photo.4.2. main canal

After the asphalt road up to end Main Canal (6.55 km), one gated head regulator structures, five. Secondary canals off takes and three steel bridges were incorporated in the design document. But, in the study time all these work was not completed because of scarcity of budget.
The Fentale main canal as well as the irrigation farm is on porous media and most of the drainage water inflow as subsurface inflow.

The main canal loss at different section of the canal is determined by conducting series of measurement at different sections of the canal for different discharge rate released from the diversion weir (high, medium and low). These are Q high =8.04 m3/s Q medium =4.61 m3/s and Q low = 3.47 m3/s.

The main canal has been designed to carry maximum discharge of 18m3/sec to irrigate the intended net irrigation area of 15222ha. Currently, since the irrigated area is around 4521 ha, the maximum discharge required for irrigation and flow in the main is around 4.9731m3/sec. But, the actual flow measured in the main canal during the medium flow is about 4.606m3 which is below the expected amount, because of the silt up of the canal. The main canal run along the periphery of Nura Hira farm and extends to foot of mount Fentale which is about 49.6 km up to rail way . Based on the soil type, the main canal was lined with geo membrane and some part is lined with concrete to minimize the canal seepage. However, the geo membranes are damaged by erosion in rainy season and by human theft. In most parts, irrigators are not using flow turnout structures constructed because they are either cannot divert the required discharge according to their interest or filled with silt. Farmers practices diverting and closing irrigation water to fields using traditional diverting system. This traditional diverting system worsens the destruction of main canal and creates over flooding the field especially during night time.
The responses for the schemes generally confirm the assessments made by other methods.

Rather few farmers consider conditions at five years ago, despite the improvements that have been made over the years. However, there are also rather few farmers that consider conditions to be worse. It is consistent with the judgment of a majority of the farmers surveyed that the water supply operations and distribution at the outcome of the asset survey that characterized the condition of the system as generally “good” or “reasonable”.

Water shortage is a problem at most times of five year. On the other hand, the majority of farmers believe the system has deteriorated over the last five years and that supply/operations have worsened in parallel. The asset survey showed that the canals and many of the structures were in poor condition. A majority of farmers interviewed consider that the scheme is currently in “good” or “reasonable” condition, as shown on (table 4.4.) However, there appears to be a gradual deterioration in the system, since substantial numbers believe its condition was better five years ago.

Table 4.4 Capacity of farmers to carry out repairs/maintenance

Scheme	**Questionnaire**	**Responsible**	**View%**
Main canal	Farmers’ views on responsibility for canal maintenance	OIDA WUA Don’t know/other	**65** **17** **18**
Main canal	Farmers reporting a contribution to maintenance	WUA	**50**
Main canal	Farmers’ perceptions of water supply and system operation	WUA	**60**
Main canal	Capacity of farmers to carry out repairs/maintenance	WUA	**65**

- **Branch Canal - I**

Branch Canal- I is about 50 km length up to commanding point of Haro- Arba area, the canal capacity is about 6.72 m3/sec.

This canal branches at a distance of 6.708 km upstream from the asphalt road. Within this stretch gated cross regulator structure, one road crossing on the Addis Abeba – Harar highway, two Cattle Crossings, and five Cross drainage structures are considered.Branch canals were unlined and construction is still not completed.

But, this branch canal is under construction because of shortage of budget which is out of the completion period

- **Branch Canal- II**

Branch Canal-II has a total length of 31.34 km. and canal capacity is about 5m3/sec. Within the first 29.7 km ten gated cross regulators, one emergency spillway (escape), four primary canal head regulators, nine secondary canal head regulators, three main road crossing, twelve drop structures (with drop height varying 1.00~2.50 m) and eighteen cattle crossing are incorporated.

At the 29.7th km the canal cross Addis Ababa-Harar road and after 440 m crosses Addis Ababa - Djibouti RW Line the same as branch canal I branch canal II is also under construction.

The secondary, the tertiary and field canals are also designed to receive their water through underground PVC pipes.

- ❖ This canal system is a very good conveyance system which should have to be appreciated, because of no treat of evapo-transpiration and different percolation losses caused by unlined and open canals.
- ❖ this type of canal layout is also is gained being economical according to the field report.
- ❖ But only the main branch canal is under construction the whole designed system was not completed.

4.1.3.3. Canal Alignment (Canal Layout)

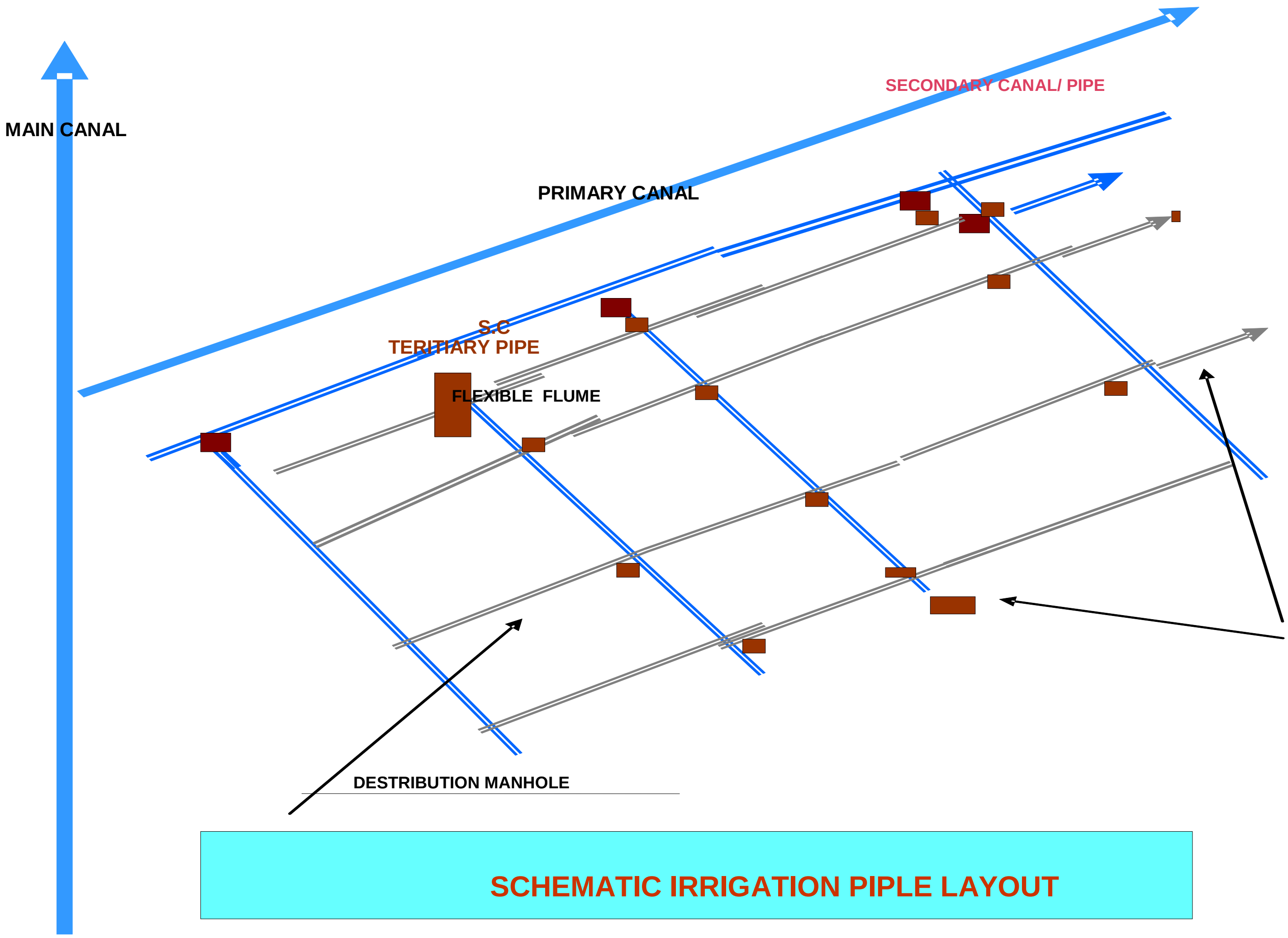


Fig.4.3. Layout of Irrigation canal net works

4.1.3.4. Canal Sections

In Fentale project case, two types of canal sections were adopted:

- ❖ Trapezoidal canal section some part almost 10% lined with polyethylene geo-membrane over lain by 20 cm thick riverbed material in gabion.
- ❖ Rectangular section with some part (10%) concrete bed and masonry sides.

Trapezoidal sections are provided in reaches where the geological formations are soil and where convenient to maintain whereas, rectangular sections are aligned at the reaches where the formations are rocky.

- ❖ It was an appropriate design and the canal section was constructed as per the design.
- ❖ But the periphery of the canal was not protected from the cattle foot and the free board is gating shorter than the designed and and some part of the canal seems with no free board

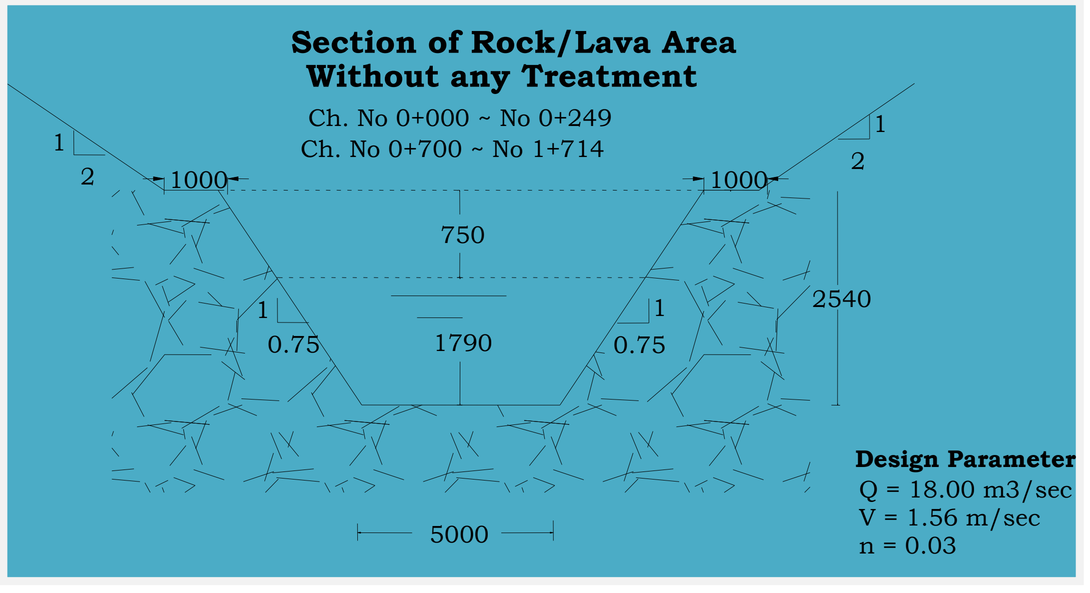


Fig.4.4. Trapezoidal section part of the main canal

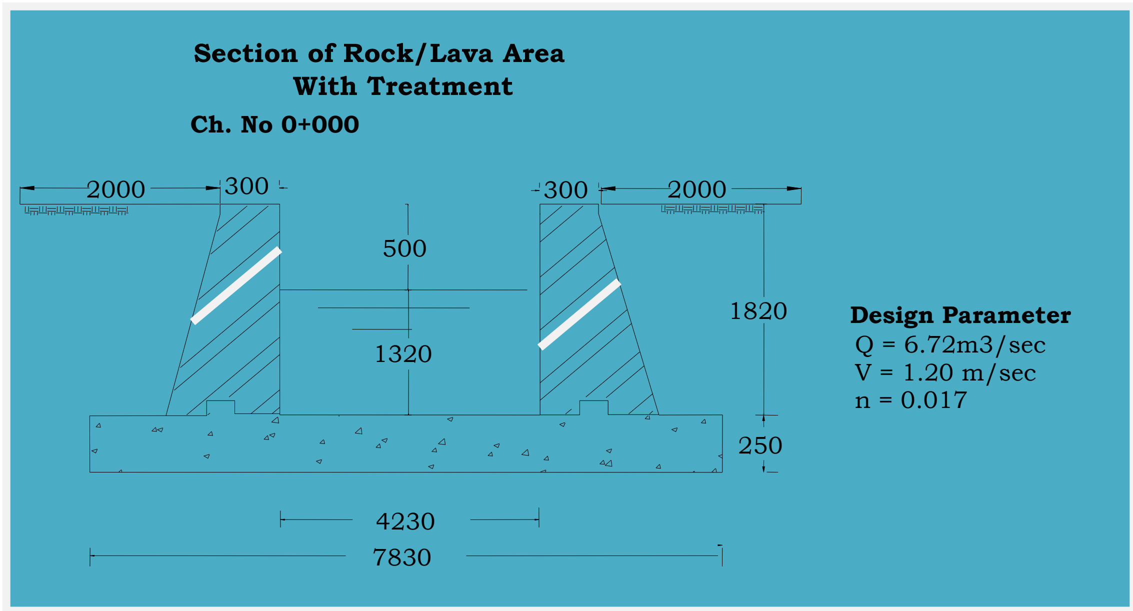


Fig.4.5.Rectangular section part of the main canal

4.1.3.5. Canal Lining

In most cases, canal lining is recommended to reduce water loss through seepage. Excessive seepage from unlined canal reduces the designed duty. The same for Fentale case,

As per the geologist report, the main canal in most of its reach passes through pervious strata with high permeability.

Therefore, there is very high transit losses in the canal, thus reducing the benefits and also create water logging of land adjacent to the canal. (design report OWWDSE).

- ❖ The design report underlined all the conveyance canal must be lined by its appropriate lining materials.
- ❖ For Fentale case, geo-membrane and cement concrete are considered and recommended on main canal and branch canals.
- ❖ However, almost all the Main and branch canals were earthen canals.
- ❖ Only 10% of the entire main canal was lined, and the longest part of the canal, almost 90% is unlined.

Photo.4.6. Canal lining with geo-membrane

4.1.3.6. Drainage System

A drainage system has three components:

- A field drainage system, which prevents ponging of water on the field or controls the water table
- A main drainage system, which conveys the water away from the farm
- An outlet, which is the point where the drainage water is led out of the area.
- Currently, Lake Beseka has been expanding drastically. Fentale farm is one of the large-scale irrigation schemes partially falling in the drainage area of Lake Beseka. The source of irrigation water for the farm is river Awash and irrigated by gravity.

- As the previous study in 1998 pointed out, (as cited in MoWE, 2011) the nearby Fentale Irrigation, which drain its excessive irrigation superficially and/or as deep percolation into the lake and the presence of hot springs, which supply the lake with groundwater, are supposed to be responsible for the rising Lake level and corresponding increase in the aerial extent.
- Therefore, the irrigation water management study is one of the focusing areas to evaluate the water managements of Fentale, irrigation scheme found in the lake catchment area whether it has impact on the drastic expansion of the lake and to determine the surface outflows drain to Lake Beseka.
- There are also off takes made by farmers but have no gates to control the flow of water. As discussion was made with the users of the scheme, they irrigate their crops at night since there is shortage in day time. Therefore, if the farmers do not use the irrigation water in the off takes day and night, it drains to lake Beseka
- As shown in Photo. 4.7, some part of the drainage system is under a threat of collapse because, in most parts, irrigators are not using flow turnout structures constructed because they are either cannot divert the required discharge according to their interest or the structure is filled with silt because lack of maintenance.

Photo. 4.7. Cross drainage structure

4.1.3.7. Current Status of irrigation Structures

- On the main canal, forty four drop structures were constructed from which the forty three were designed and one is additionally constructed by design amendment. However, two were damaged & others need maintenance.
- On the same canal, there were sixteen off takes implemented. But three are without first plan. From these structures, four (4) were damaged & others need maintenance.
- The Ten cross drainage structures were constructed as per the design document and two of them need maintenance
- From the planned three road crossing culverts, only one was constructed because of budget dalliance.
- About the omitted canal crossing culvert there was a complain among the community. Because, the interval of the culverts should have to be 3km as per the design. But practically, there was an interval of even more than 6km between some culverts.
- Generally, the completed structures were not as per the design but so many design amendments and revision were made on the basic design document after the implementation was started.

Table 4.4 :Structures constructed on the Main Canal

Type of structures on the main canal	Designed works in numbers	Constructed (implemented) in numbers
Drops structure	43	44
Off-take	13	16(with49.6km)
Cross drainage	10	10
Road crossing culvert	3	1
Stream crossing	13	14 (5 were damaged& others need maintenance)
Cattle crossing	3	6 (All need maintenance)
Chutes	2	2(450m&150m,long)
Rail way crossing	1	1 Good position
Steel bridges	3	Good position
Aqueduct	1	1 (Damaged)

- The other two branch canals were still under construction and it has also an impact on achieving the planned irrigation area this showed there was no sustainable schedule of work.

Table 4.5 :Structures constructed on the branch Canal II

		Designed	implemented	Remark
Drops structure		-	14	Under construction
Off-take		13	15	Under construction
Road Crossings		-	5	Under construction
Road Crossing Culverts		-	2	Under construction
Stream crossing		-	12	Under construction
Cattle crossing		-	10	Under construction
Rail way crossing		-	2	Under construction

4.1.3.8. Flow Measurement

To determine the amount of water applied by the irrigators to the field, during an irrigation event, three inches (3’’) Parshall flumes were installed at the entrance of test plot. Frequent readings were taken when the farmers irrigate the test plot. Irrigation was continuing until the farmers’ thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test plot, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test plot being irrigated. The discharge was computed using equation (3.11) in section (3.7.2) and the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer’s decide that enough water has been applied to their fields.

The amount of inflow D per furrow was computed as follows:

$$\mathbf{D} = \frac{Q_{av}\,T_{app}}{10A}$$

$$A = W*L\ (m^2)$$

where: D= depth of water applied (cm),

A=area over which water is applied (m^2),

L = furrow length (meters)

W = furrow spacing (meters)

T_{app} = application time (sec),

Qav =average discharge rate (lit/sec).

To measure the cross section of the furrow, the width of the furrow was determined by selecting three furrows per test plot. The width of each furrow was measured at three points per furrow (top, middle and end) dividing into seven equal segments, and then the average width was calculated. The depths of each segment of the furrow were measured. The area of each segment is the product of the width of segment and its average depth. The areas of the segments are summed to determine the total cross sectional area.

4.1.3.9. Furrow Geometry and Spacing

Furrow cross sections on each selected plots were measured by selecting three furrows per test plot and at three equal points (at head, middle and tail end of the furrow along the flow direction as described on the(Fig.4.10.) furrow cross section was irregular in shape. The average cross sectional area of the furrows in the scheme found to be 0.03 m^2. The average depth and top width of the furrow varied from 12 cm to 15 cm and from 38 cm to 40 cm, respectively. The average spacing of furrows varied between 0.40 m to 0.45 m with mean of 0.42.5 m. The furrow in the scheme could be characterized.

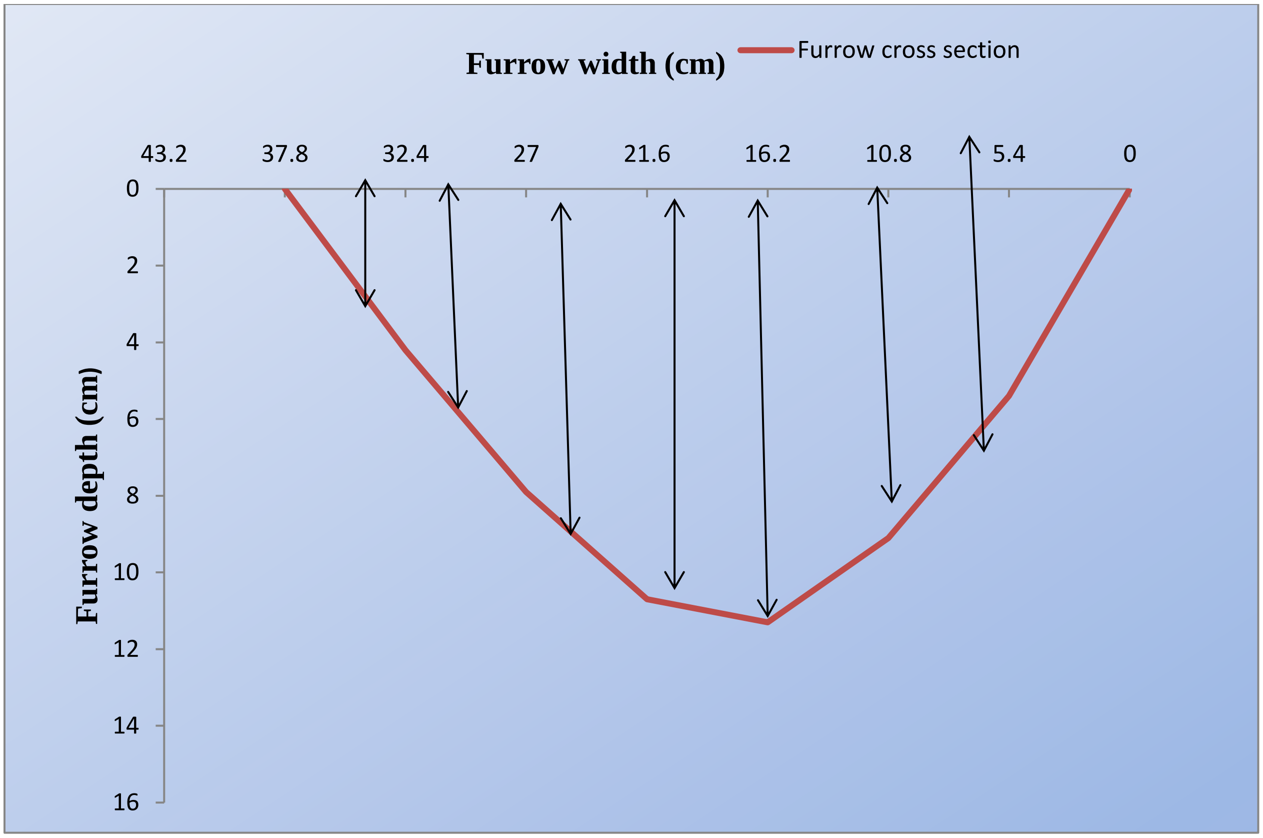


Fig4.10. Farrow cross section

4.1.3.10.Advance and Recession Curve

The time required for the water to advance to the end of the field length is an important consideration for managing surface irrigation systems. The intake opportunity time is the interval during which water will infiltrate at a specified location. The opportunity time for each furrow was determined from the advance and recession times and varied from 5.36 minutes for 12.45 m length of furrow to 10.77 minutes for 20 m length furrow of the test fields with mean of 7.88 minutes. Typical advance and recession curve of one farmer's field is shown in(Figure 4.11)

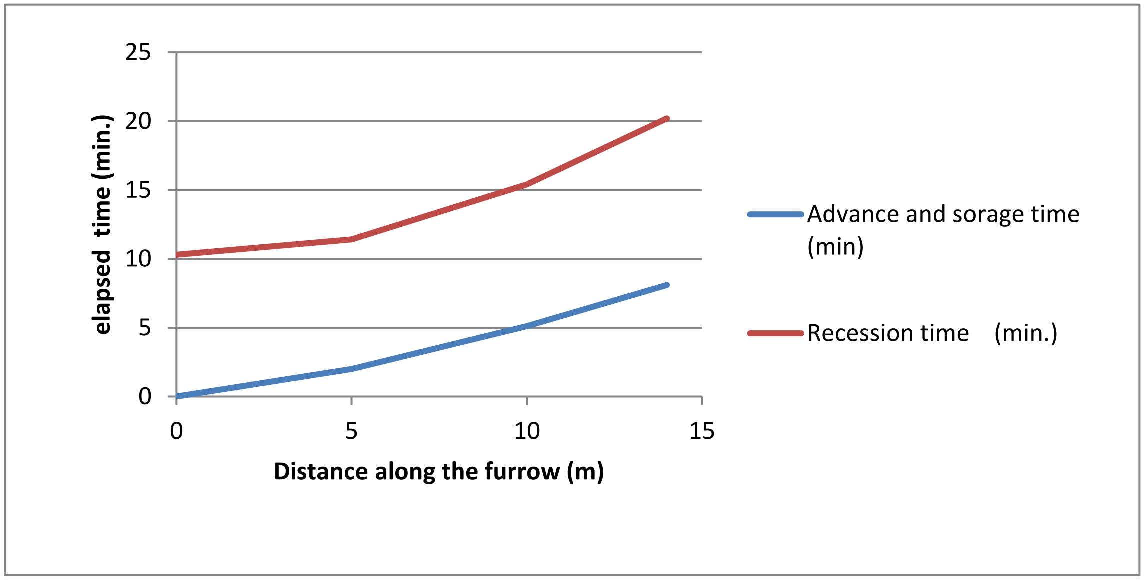


Figure 4.11. Advance and Recession Curves of Alemayehu Bekuma field plot

4.2. Performance evaluation

The performance of any irrigation system is the degree to which it achieves the desired objectives. Hence, evaluations are useful through a number of tools in order to improve the overall management of the system and enhance efficiency. According to Molden et al. (1998), the principal objective of evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. Moreover, performance is to be assessed to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints; to better understand determinants of performance, to compare the performance of a system with others or with the same system overtime.

As many farmers are managing irrigation, scheme do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993).

4.2.1.Technical Performance Evaluation

Technical performance evaluation analysis was conducted using technical efficiencies indicators. The technical evaluations were made for the following indicators; namely, conveyance efficiency, application efficiency, distribution efficiency, and water storage efficiency to evaluate the performance of the project studied.

4.2.1.1. Determination of Conveyance Efficiency

The average conveyance efficiency was computed and the result was found as follows.

- for main lined canal is 95% and
- for main unlined canals 51% is

But, it can be increased 80-85 % by minimizing the conveyance losses through adoption of appropriate measures that minimizes deep percolation losses.

- The main canal of Fentale irrigation scheme conveys the irrigation water from the river diversion point to the upstream of the command area.
- The designed capacity of the main canal is 18m3/sec runs for about 49.6km
- Command area 15222 ha, Irrigation duty 1.14 l/sec/ha for 24 hour.
- The main canal also supplies irrigation water to the pond at night. Hence, the main canal operates for 24 hours while irrigation takes place for a maximum of 12 hours a day in the crop season.
- The lined part of the main canal was very small it was only 10% of the whole main canal.

Table 4.6: Main canal conveyance efficiency and loss using velocity area method

Canal type	Segment No.	Distance b/n points (m)	Inflow (l/s)	Out flow (l/s)	Conveyance loss (l/s)	Conveyance loss (l/s/m)	Conveyance efficiency (%)
Lined main canal	1	600	147.15	139.11	5.1	0.0085	94.5
	2	600	148.00	145.00	5.2	0.0087	97.9
	3	600	134.15	127.60	7.3	0.0122	95.5
	4	600	128.96	122.45	8.3	0.0138	94.7
Average						0.01067	95.5
Unlined main canal	1	600	120.35	66.71	11.6	0.0193	55.3
	2	600	108.71	50.83	13.9	0.023	46.5
Average						0.0192	51

4.2.1.2. Determination of Application Efficiency

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop.

- Table 4.7 presents summary of the results of application efficiency (Ea) for test plots of the three field locations (upstream, middle stream and downstream).
- The obtained values were 57.7 %, upstream,
- 68.4% middle stream
- 72.9 % for downstream users
- This indicates that the upstream irrigators are inefficient by applying excess water to their fields. Those irrigators, who are getting less access to water, were able to efficiently utilize what they have got even if the uniformity is poor.

- ❖ In general, according to Michael (1997), water application efficiency decreases as the amount of water applied during number of irrigation event increases.

Table 4.7: Application efficiency for three field location test plots

Location	U/S			M/S			D/S		
Stages	WAD (mm)	AMS (mm)	Ea (%)	WAD (mm)	AMS (mm)	Ea (%)	WAD (mm)	AMS (mm)	Ea (%)
Initial	79.0	28.5	36.1	61.5	31.2	50.7	68.3	46.6	68.2
Dev`t	73.0	49.8	68.2	46.9	31.3	66.7	48.4	34.5	71.3
Middle	84.2	57.9	68.7	75.2	66.1	87.8	66.4	52.6	79.2
Average			57.7			68.4			72.9

Note:-WAD, Water applied depth, AMS, Actual moisture storage.

4.2.1.3. Adequacy or storage efficiency

Storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application.

The water storage efficiencies (Er) computed by monitoring soil moisture before and after irrigations.

Table 4.8 presents The average results obtained werer

- ❖ For upstream 97.7%,
- ❖ For Middle stream 98.0%
- ❖ For downstream 98.8%,locations of the test plots .
- ❖ According to Raghuwanshi and Wallender (1998), the recommended storage efficiency is 87.5%. Thus, the storage efficiency of the scheme indicated that the irrigation system was adequate in fulfilling the soil moisture required for good productivity of the crops.

Table 4.8: Adequacy or storage efficiency

Stages	Field location in the scheme								
	U/S			M/S			D/S		
	SMD (mm)	AMS (mm)	Er (%)	SMD (mm)	AMS (mm)	Er (%)	SMD (mm)	AMS (mm)	Er (%)
Initial	18.55	17.79	96.0	18.90	18.10	95.70	20.80	20.58	98.94
Development	26.36	25.86	98.0	28.90	28.65	99.30	28.88	28.52	98.75
Mid-season	46.30	45.89	99.1	55.67	55.08	98.90	47.60	47.00	98.73
Average			97.7			98.0			98.8

4.2.1.4. Distribution uniformity

Distribution uniformity (DU) is used to express the variation in depths of application or supplied volumes. and evaluated by monitoring the depth of water infiltrated into the root zone depth using soil moisture content.

- Table 4.9 presents summary of the results of The average results obtained were:
- For upstream 91.4%,
- For Middle stream 90.4%
- For downstream 94.8%.

(FAO, 1992) also suggested that in an average rotational supply with adequate management and communication, having distribution uniformity of 65% as “sufficient” and DU of 30% as “poor”. Thus, the average values of DU of the scheme indicate the distribution uniformity of irrigation water in the selected farmers’ field was sufficient.

Table 4.9: Distribution uniformity of the three field location

Stages	Field location in the scheme					
	U/S		M/S		D/S	
	0 - 30	30 - 60	0 - 30	30 - 60	0 - 30	30 – 60
Initial	92.9	94.6	90.4	88.7	93.9	92.0
Development	90.2	81.9	82.6	97.1	94.2	92.7
Mid-season	94.7	90.2	96.4	96.6	94.8	93.4
CUC average %	92.0		89.8		94.90	

4.2.1.5. Christiansen uniformity coefficient

The Christiansen's uniformity coefficient (CUC) obtained were

- ❖ For upstream 92.0%,
- ❖ For middle stream 89.8%
- ❖ For downstream 94.9%
- ❖ Table 4.10 presents summary of the results of The Christiansen's uniformity coefficient (CUC) obtained from the three field locations (upstream, middle stream and downstream fields of the scheme.
- ❖ The reason for achieving higher values of CUC in this study might be due to the flatness of the test plot fields and uniformity (clay nature) of soil texture.

Table 4.10: Christiansen's uniformity coefficient of the three field location

Stages	Field location in the scheme					
	U/S		M/S		D/S	
	0 - 30	30 - 60	0 - 30	30 - 60	0 - 30	30 – 60
Initial	98.2	95.4	92.3	73.7	91.5	92.4
Development	91.2	79.6	86.2	97.0	96.7	96.6
Mid-season	97.3	87.1	94.7	98.4	96.1	95.6
DU average	91.4		90.4		94.8	

But, Irrigation Efficiency (from The design Document) suggested that, the determination of irrigation water requirement should also account for losses of water incurred during conveyance, distribution and application to the field. Furthermore, water may be needed for leaching of accumulated salts from the root zone. These two aspects should be accounted for in the irrigation requirements. These losses are expressed as a fraction of efficiencies. Based on the level of the technical and management capacity of the farmers expected to acquire in the future training the following irrigation efficiencies have been considered for the scheme.

- ❖ Conveyance Efficiency (Ec) = 0.95
- ❖ Field canal Efficiency (Ed) = 0.90
- ❖ Application Efficiency (Ea) = 0.70
- ❖ Overall irrigation efficiency (Ep) = 0.60
- ❖ This was not the same value as the study shows that irrigation efficiency is a value which can only be estimated in the design stage.
- ❖ It depends on many factors which also vary with time. Literature (Nugteren en Bos 1983) gives average and indicative data, but the real values can vary considerably from case to case.

4.2.2. Economic performance evaluation

- ❖ The economic efficiency of the project was evaluated by comparing the benefits gained from the onion yield with the total cost of production.

- ❖ The necessary cost data's for onion production during the study period were collected from the irrigators at the plot level.

4.2.2.1. Water productivity in terms of water Applied (CWP)

The result obtained was as follows.

- ❖ for upstream, 12.10 kg/m3,
- ❖ for middle stream 18.14 kg/m3
- ❖ For downstream 20.30 kg/m³ location of the test plots
- ❖ The result indicates that the reduction in yields is because of different cultural practices in the fields.

Here, the productivity for the farmer's field located at middle stream of the scheme had the highest return per unit of water consumed (18.1kg/m3). May be because of good cultural practices of the farmers.

Table.4.11: Onion Production per unit water applied

Field location	Field size (ha)	Water applied (mm)	Water applied (m3)	WateApplied (m3/ha)	Bulb weight (kg)	Bulb weight (kg/ha)	CPW (kg/m3)	EWP (birr/m3)
U/S	0.04554	723.6	329.5	7236.0	398.8	87571.4	12.10	8.59
M/S	0.07904	505.6	399.6	5056.0	725.0	91721.6	18.14	9.00
D/S	0.04994	364.7	182.1	3647.0	369.6	74011.6	20.30	7.26

The analyzed input cost breakdown and the total net benefit per unit of water applied results are tabulated in Tables 4.12

Table 4.12: Costs of water applied

Field location	Area (ha)	VWA (m3/season)	VWA (m3/ha/season)	Water cost (birr/1000m3)	TWC (birr/plot/season)	TWC (birr/ha/season)
U/S	0.04554	329.50	7235.2	3.00	0.99	21.71
M/S	0.07904	399.60	5056.0	3.00	1.20	15.17
D/S	0.04994	182.10	3646.6	3.00	0.55	10.94

Note: CWP: is productivity of water in terms of water applied;
EWP : estimated water productivity
VWA : Volume of water applied
TWC: Total water cost productivity in terms of monitory units; an average

4.2.2.2 Total Cost of Birr/h and Birr/Plot

For Upstream 16469.96 Birr/ha 750.04 Birr/0.04554h
For Middle stream 16625.99 Birr/ha 1314.12 Birr/0.04554h
For Downstream 17246.69 Birr/ha 861.29 Birr/0.04554h

The yield of onion under farmers` condition is very low (6 t/ha) and as high as 25 t/ ha under good management practice (Getachewet al., 2009). The wide gap in yield is attributed to lack of improved varieties, poor agronomic practices and soil fertility and diseases (bulb rot and downy mildew) and insect pests (onion thrips), etc in farmers` field (Getachew and Asfaw, 2000).

- ❖ From this study, we can conclude that onion production under this project was economical.

Table 4.13: Cost break down for Onion production in 2014

Field location	Area (ha)	Cost break down (birr/plot/season)				Total cost (birr/plot)	Cost (birr/ha)
		Red onion cost	Pesticide cost	Water cost	Other cost		
U/S	0.04554	385.07	49.90	0.99	23.18	750.04	16469.96
M/S	0.07904	659.62	94.90	1.20	37.52	1314.12	16625.99
D/S	0.04994	448.62	61.20	0.55	26.87	861.29	17246.69

Remark: Labor cost includes costs for land preparation, planting, weeding, harvesting (uprooting) and transporting etc.

- ❖ The present value of benefits and costs were determined by taking current interest rate 5% and since a project had long life age, the economic efficiency was predicted for 10 years of life.

Table 4.14: Net present worth (NPw)

Field location	Area (ha)	Yield (kg/ha)	Average market price (birr/kg)	Gross benefit (birr/ha)	Total cost (birr/ha)	Net benefit (birr/ha)	$(1+r)^t$ $(1+0.5)^{10}$	NPW (birr)
U.S	0.04564	8757.4	5.0	43787.00	16479.96	27316.91	1.63	17752.71
M/S	0.07914	9172.6	5.0	45863.00	16635.99	29216.87	1.63	16930.59
D/S	0.04984	7401.6	5.0	37008.00	17226.69	19771.22	1.63	13135.72

Note: An average market price of onion is 5.0 birr/kg.

4.2.2.3. The Benefit Cost Ratio

The benefit cost ratio was computed using equation given on 3.12 and 3.14 and the result was presented on the Table 4.15 The benefit-cost ratio results observed for the three location users were:

For upstream users 2.77

For middle Stream users 2.87

For down Stream users 2.26.

The maximum economic efficiency was found in middle location irrigators (2.87) whereas the minimum economic efficiency was found in tail location beneficiary (2.26) next to upstream irrigators (2.77).

This might be due to farmers in the middle fields applied water nearly equal to the water requirement of the crop as calculated by CROPWAT software program.

In general, the analysis indicates that onion production in the scheme is economically efficient in terms of water use, since the benefit-cost ratio values of the three locations were more than one.

Table 4.15: Economic efficiency

Field location	Gross benefit (birr/ha)	Total cost (birr/ha)	Net benefit (birr/ha)	$(1+r)^t$	PV of benefits (birr)	PV of costs (birr)	B/C ratio
U.S	43787.00	16479.96	27307.04	1.63	26853.11	10827.08	2.66
M/S	45863.00	16635.99	29227.01	1.63	28126.72	12591.02	2.75
D/S	37008.00	17226.69	19781.31	1.63	22714.24	10558.5	2.14

5. SUMMARY AND CONCLUSION

5.1. Summary

The principal objective of evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency.

The optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture. This study was undertaken to characterize and evaluate the technical performance of Fentale irrigation scheme under the existing farmers' irrigation management practices.

- The average **canals conveyance efficiencies** were,

  Main lined canal, 95%

  Main unlined canal, 51%,

- A**pplication efficiency (Ea)** for test plots of the three field locations (upstream, middle stream and downstream)

  The obtained values were:

  for upstream, 57.7 %,

  for middle stream, 68.4% , and

  for downstream72.9 % users.

- **The water storage efficiencies (Er)**

Is computed by monitoring soil moisture before and after irrigations. The average results obtained were:

For upstream 97.7%,

For Middle stream 98.0%

For downstream 98.8%,locations of the test plots .

According to Raghuwanshi and Wallender (1998), the recommended storage efficiency is 87.5%. Thus, the storage efficiency of the scheme indicated that the irrigation system was adequate in fulfilling the soil moisture required for good productivity of the crops.

- **Distribution uniformity**

The results obtained for distribution uniformity(DU) is used to express the variation in depths of application or supplied volumes. by monitoring the depth of water infiltrated into the root zone depth

For upstream 91.4%,

For Middle stream 90.4%

For downstream 94.8%.

- **Christiansen uniformity coefficient**

The Christiansen's uniformity coefficient (CUC) obtained were

For upstream 92.0%,

For middle stream 89.8%

For downstream 94.9%

- **Economic performance evaluation**

Water productivity in terms of water Applied (CWP

Is the water productivity in terms of the crop water consumed

The result obtained was as follows.

for upstream, 12.10 kg/m3,

for middle stream 18.14 kg/m3

for downstream 20.30 kg/m³ location of the test plots. The result indicates that the reduction in yields is because of over-irrigation in the case of upstream field and water stress in the case of downstream fields.

Here, the productivity for the farmer's field located at middle stream of the scheme had the highest return per unit of water consumed (18.1kg/m3).

- **The benefit cost ratio was computed as follows:**

For upstream users 2.77

For middle Stream users 2.87

For down Stream users 2.26 .

The maximum economic efficiency was found in middle location irrigators (2.87) whereas the minimum economic efficiency was found in tail location beneficiary (2.26) next to upstream irrigators (2.77).

This might be due to farmers in the middle fields applied water nearly equal to the water requirement of the crop as calculated by CROPWAT software program.

- ❖ From the computation of the CROPWAT model,

The seasonal crop water requirements of Onion was 455.3mm

Effective rainfall was 145.8 mm.

Net irrigation water required 315.5 mm.

5.2.Conclusion

This study is not forwarding the most detail evaluation and characterization for this project because, the project is very huge, far from public transport access and tedious to go through when compared with the weather condition it has. But, it can be an encouragement for further studies for the sustainability and increasing efficiency of this project.

From this study, the following conclusions can be outlined.

- ❖ The most problem of this project was not only timely completion but also frequent revision of design and shortage of budget that made the project under performance.
- ❖ One of the four under sluice gates was not functional. additionally, the rest three were not opened timely for silt exclusion service.
- ❖ Most of the structures found on main canal are in need of maintenance and some are completely damaged
- ❖ Silting up was a serious problem of weir site and main and branch canals because of note proper functioning of the under sluice gate.
- ❖ Most geo-membrane was used as lining media. But, there is human interference; some part of the material is taken away or destroyed.
- ❖ The system permitted farmers to apply large volume of water to their fields combined with poor knowledge about the crop water requirements of the farmers.
- ❖ there is illegal abstraction of water observed on the main canal. .

- ❖ It can be concluded that productivity of the cropping system can be improved by minimizing water losses due to deep percolation losses and over- irrigation of the root zone and applying water according to water requirement.
- ❖ In general the analysis indicates that onion production in the scheme is economically efficient in terms of water use, since the benefit-cost ratio values of the three locations were more than 1.

5.3. Recommendation

From the study, the following recommendations are forwarded for sustainable resource utilization.

- ❖ The under sluice gates must be opened when there is enough flow to flash out the deposited silt.
- ❖ There should be trash rack on the in let which prevent debris from entering conveyance system or blocking the inlet
- ❖ Timely design and construction of irrigation structures contributes for equity of water distribution among farmers at different locations and for and achieving the most plan of production.
- ❖ Proper and timely maintenance of these structures improves the performance..
- ❖ Any organ, which belongs, should give attention on guidance and support of farmers in developing and introduction of appropriate depth of irrigation, irrigation interval, in addition to improving physical infrastructure of the scheme (on aqueduct, dykes and other structures maintenance and construction) for future use.
- ❖ The efficiency of the project needs improvement, therefore the following measures can be taken:
- ❖ Regular maintenance of cracks, holes, furrows, damages and leaks in water control structures is simple and effective to improve irrigation efficiency
- ❖ Control of weed growth in the unlined canals, waterways and field channels can improve canal conveyance efficiency
- ❖ The application efficiency can be improved by proper land leveling and grading which are the prerequisite for efficient water application.

- Preparation of extra drainage system is necessary for the scheme.to avoid accumulation of excess water in the lower spots that leads to deep percolation loss.
- Lining of channels with impervious materials is the better option in such Projects where deep percolation loss is a problem.

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7.APPENDICES

7.1. Appendix Tables

Appendix Table 1. Average measured flow discharge data for main canal

Trial No.	length of each segment (m)	Average flow cross-section (m)		Flow area (m2)	flow time (sec)	Flow velocity (m/sec)	Flow discharge (lit/sec)
		Width	Depth				
Main canal							
A (Inlet)		0.59	0.42	0.246	16.8	0.595	146.25
B (Outlet)	434	0.555	0.44	0.244	17.3	0.578	141.16
C (Inlet)		0.56	0.44	0.244	17.3	0.578	141.16
D (Outlet)	434	0.525	0.43	0.226	16.6	0.602	135.99
E (Inlet)		0.53	0.43	0.226	16.6	0.602	135.99
F (Outlet)	434	0.5	0.44	0.220	17.1	0.585	128.65
G (Inlet)		0.50	0.44	0.220	17.1	0.585	128.65
H (Outlet)	434	0.46	0.45	0.207	17.2	0.581	120.35
I (Inlet)		0.46	0.45	0.207	17.2	0.581	120.35
J (Outlet)	665	0.485	0.39	0.189	17.4	0.575	108.71
K (Inlet)		0.49	0.39	0.189	17.4	0.575	108.71
L (Outlet)	665	0.5	0.33	0.165	17.4	0.575	94.83

Appendix Table 2. Average furrow geometry of experimental plots

Location of the plot			Furrow width			Average furrow (m2)					
	FL (m)	Plot width (m)	TW (m)	BW (m)	Av. width (m)	depth (m)	x-section area	Furrow area	Total plot area (m2)	Av. slope (%)	Intake opport. time (min.)
P-1	12.30	12.20	0.37	0.10	0.24	0.11	0.03	4.55	150.06	0.40	7.58
P-2	13.00	12.10	0.40	0.15	0.28	0.12	0.03	5.20	157.30	0.20	8.12
P-3	14.10	10.50	0.38	0.17	0.28	0.10	0.03	5.36	148.05	0.30	9.33
U/S (sum)								15.11	455.41		8.34
Average	13.13	11.60	0.38	0.14	0.26	0.110	0.03	5.04	151.80	0.30	8.34
P-4	20.00	13.60	0.35	0.12	0.24	0.11	0.03	7.00	272.00	0.20	10.77
P-5	16.40	14.00	0.35	0.12	0.24	0.10	0.02	5.74	229.60	0.10	7.93
P-6	16.50	17.50	0.40	0.17	0.29	0.13	0.04	6.60	288.75	0.10	8.89
M/S(sum)								19.34	790.35		9.20
Average	17.63	15.03	0.37	0.14	0.25	0.11	0.03	6.45	263.45	0.13	9.20
P-7	15.30	10.70	0.40	0.18	0.29	0.12	0.03	6.12	163.71	0.20	6.36
P-8	16.40	12.80	0.40	0.15	0.28	0.12	0.03	6.56	209.92	0.30	6.54
P-9	12.45	10.10	0.35	0.10	0.23	0.11	0.02	4.36	125.75	0.30	5.36
D/S (sum)								17.04	499.38		6.09
Average	14.72	11.20	0.38	0.14	0.26	0.12	0.03	5.68	166.46	0.27	6.09
Scheme average	15.16	12.61	0.38	0.14	0.26	0.11	0.029	5.72		0.23	7.88

FL = Furrow length, TW =Top width, BW = Bottom width

Appendix Table 3 Applied water depth profile for three growth stages

Farmers field location	Crop stage	Tc(sec)	Flume height (cm)	Respective discharge (l/s)	Area (m2)	Total volume (m3)	Applied depth (mm)	No. of irrigation events
U/S	Initial	20140	5.1	1.79	455.4	35.9	78.8	2
	Dev`t	18030	5.2	1.82	455.4	32.8	72.0	2
	Mid-season	22201	5.1	1.77	455.4	39.2	86.2	4
	Late season	21518	5.1	1.79	455.4	38.4	84.4	1
	Average	20472	5.1	1.79	455.4	36.6	80.4	9
M/S	Initial	27370	5.2	1.8	790.4	49.8	62.4	2
	Dev`t	20678	5.2	1.8	790.4	38.0	47.6	2
	Mid-season	31002	5.2	1.8	790.4	57.1	72.1	3
	Late season	24906	5.9	2.2	790.4	55.8	70.6	1
	Average	25989	5.4	1.93	790.4	50.3	63.2	8
D/S	Initial	15427	5.3	1.9	499.4	28.9	58.3	2
	Dev`t	10028	5.4	1.9	499.4	19.1	38.4	1
	Mid-season	15219	5.2	1.8	499.4	27.8	56.4	3
	Late season	13308	5.6	2.0	499.4	27.3	55.4	1
	Average	13496	5.4	1.91	499.4	25.8	52.1	7

Appendix Table 4 Monthly Rainfall

Element- Monthly Rainfall in mm

Region- Oromia

Station- Metehara

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1985	6.3	0.0	29.6	76.6	108.5	12.0	166.7	153.7	41.9	4.4	0.5	0.0	600.2
1986	0.0	41.6	43.2	27.8	14.0	55.0	64.3	67.1	51.1	4.0	0.0	7.0	375.1
1987	0.0	24.1	71.6	78.2	74.8	0.0	53.6	110.4	8.0	2.8	0.0	0.0	423.5
1988	13.6	29.6	11.9	23.7	7.8	12.1	156.5	136.1	104.3	18.0	0.0	11.9	525.5
1989	0.0	28.0	104.8	119.9	7.5	82.1	48.7	92.7	28.2	5.6	0.0	12.7	530.2
1990	0.5	220.8	58.1	62.9	1.8	0.9	146.4	76.9	82.4	2.1	0.0	0.0	652.8
1991	0.0	54.3	56.1	46.7	53.3	15.4	137.0	132.0	49.6	11.7	0.0	0.0	556.1
1992	25.8	50.3	0.0	75.8	16.8	62.4	90.0	157.6	62.2	49.6	5.7	2.3	598.5
1993	43.8	59.5	0.0	139.6	57.3	23.7	101.4	103.7	41.6	21.9	0.0	56.9	649.4
1994	0.0	0.0	6.5	21.4	55.4	38.6	248.4	131.6	39.6	0.1	12.7	1.9	556.2
1995	0.0	43.5	81.9	44.0	10.5	28.5	47.3	144.1	57.7	0.5	0.0	0.0	458.0
1996	27.6	0.0	97.3	35.1	80.5	26.5	205.1	100.5	52.6	1.6	7.5	0.0	634.3
1997	29.7	0.0	12.6	44.3	11.5	35.1	139.7	53.8	20.4	112.4	14.6	0.0	474.1
1998	0.8	18.1	76.6	34.2	14.9	4.7	78.2	135.6	54.0	78.0	0.0	0.0	495.1
1999	0.0	0.0	73.6	6.2	15.9	16.7	136.1	151.2	16.4	76.2	2.2	0.0	494.5
2000	0.0	0.0	1.8	20.7	36.9	29.6	135.9	152.7	47.0	47.3	11.9	9.4	493.2
2001	0.0	13.6	92.7	26.3	12.7	20.2	154.8	82.8	15.3	7.1	0.0	1.6	427.1
2002	2.6	0.0	73.3	19.3	9.3	10.2	43.0	80.8	16.8	0.0	0.0	21.2	276.5
2003	4.6	19.4	33.6	13.7	0.0	29.5	118.9	186.0	31.0	0.0	3.2	15.7	455.6
2004	35.1	3.2	84.0	142.4	0.0	21.2	90.3	123.9	39.3	15.9	4.5	0.0	559.8
2005	19.3	0.0	47.2	54.3	75.5	35.7	146.4	138.4	21.6	0.0	5.2	0.0	543.6
2006	0.9	29.3	33.9	33.4	10.0	26.8	142.1	65.0	22.8	37.5	0.8	65.1	467.6
2007	9.1	44.0	105.4	19.9	20.3	6.5	124.0	157.5	69.7	4.7	17.3	0.0	578.4
2008	0.4	0.0	0.0	26.2	62.2	12.4	197.0	95.9	15.3	49.1	58.3	0.0	516.8
2009	84.8	0.0	11.4	16.1	14.1	29.7	54.7	86.6	37.4	69.6	2.5	37.3	444.2

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2010	0.0	31.5	48.8	38.6	123.6	16.8	146.4	100.5	68.9	0.0	13.0	0.0	588.1
2011	0.0	0.0	28.0	0.0	29.8	55.7	57.2	198.2	80.2	0.0	5.3	0.0	454.4
2012	0.0	0.0	16.3	27.6	47.0	6.9	161.7	98.6	31.4	0.0	0.0	0.0	389.5
Mean	10.9	25.4	46.4	45.5	34.7	25.5	121.1	118.4	43.1	22.1	5.9	8.7	507.8
STDV	19.3	43.2	35.0	37.2	33.8	19.5	53.0	37.1	23.6	30.7	11.5	17.1	88.0
CV	1.8	1.7	0.8	0.8	1.0	0.8	0.4	0.3	0.5	1.4	2.0	2.0	0.2

Appendix Table 5 Monthly Minimum Temperature

Element- Monthly Min. Temp. in ^{0}C

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1966	12.3	17.1	15.9	19.1	17.8	21.3	20.7	19.3	15.1	16.2	-	8.7	16.7
1967	10.5	14.8	18.5	18.3	18.5	19.1	20.2	19.2	19.4	16.8	17.6	11.3	17.0
1968	10.4	18.2	17.1	18.9	18.1	20.7	19.6	18.5	18.4	15.2	14.8	13.4	16.9
1969	18.3	16.9	18.5	19.3	20.1	22.3	22.1	19.8	19.6	15.3	14.7	10.9	18.2
1970	16.7	16.2	18.6	18.8	19.8	22.9	20.9	19.8	18.4	16.2	10.2	10.7	17.4
1971	13.4	11.4	15.9	17.9	19.4	21.2	19.5	18.5	17.9	14.9	14.9	12.3	16.4
1972	14.1	16.4	16.3	19.3	17.2	19.7	21	19.6	18.5	16	15.6	15	17.4
1973	14.7	13.9	17.8	20.5	20.2	21.7	21.1	21	20.1	15.4	13.1	9.5	17.4
1974	13.4	16.3	18.5	15.9	18.6	21	20.2	20.3	19.3	15.8	11.1	11.9	16.9
1975	11.9	16.3	18.1	19	19.3	20.7	19.3	19.6	19	14.4	11.4	10	16.6
1976	12.3	17.1	17.9	18.6	19.7	21.4	20.1	18.6	18.4	15.3	14.1	13.6	17.3
1977	18.4	14.3	17.7	18.6	19.3	21.4	21	19.8	19.3	18.8	15.2	14.2	18.2
1978	12.9	16	18.7	18.5	20.4	21.7	19.6	19.1	18.5	16.5	13.7	14.1	17.5
1979	16.9	13.6	16.9	17.8	18.8	20.8	19.8	19.5	19.2	15.7	11.2	14	17.0
1980	14.1	16.8	19.8	19.4	19.2	22.7	20.6	19.6	19.4	16.5	14.7	11.3	17.8
1981	13.3	13.1	17.7	17.7	17.5	20.8	20.5	19	18.6	15	12.5	11.3	16.4
1982	16.6	18.1	17.3	18.2	18.2	20.4	20.3	19.1	18.4	15.1	15.6	15.4	17.7
1983	13.5	18.1	20.2	19.8	20.1	20	20.7	20.2	19.5	15.1	12.8	12.8	17.7
1984	11.1	11.2	15.9	18	19.3	20.6	19.4	20.1	18.3	13.9	15.5	14.4	16.5
1985	13.1	13.9	17.9	18.7	18.4	20.8	18.4	17.8	18.0	15.5	13.3	12.3	16.5
1986	9.8	18.4	17.6	19.9	19.8	20.9	19.4	19.7	18.6	15.6	13.8	13.6	17.3
1987	13.6	15.0	19.3	17.2	18.7	22.9	22.1	20.2	20.2	17.8	12.7	13.6	17.8
1988	16.7	18.8	17.9	20.0	19.1	22.3	20.6	19.4	19.4	16.7	10.0	12.1	17.7
1989	13.0	15.9	17.8	18.7	16.0	19.7	19.9	19.2	19.0	15.2	14.5	18.0	17.2

1990	14.7	18.8	17.6	17.6	20.2	22.6	20.0	19.9	19.8	15.1	14.7	12.2	17.8
1991	16.4	18.2	19.5	18.7	19.2	21.7	20.4	19.8	19.5	15.7	12.8	13.6	18.0
1992	16.9	19.1	20.5	20.3	19.8	21.5	20.3	19.9	18.6	16.8	15.0	16.8	18.8
1993	17.3	16.3	15.5	19.7	19.4	21.9	20.3	20.3	20.6	18.3	14.3	12.2	18.0
1994	11.9	14.8	20.1	20.8	19.9	21.8	19.6	19.5	18.5	15.4	14.3	13.0	17.5
1995		17.4	18.7	19.7	19.8	21.1	21.2	20.0	18.9	17.0	13.2	17.1	18.6
1996	17.7	15.2	20.1		19.7	21.4	20.2	20.1	19.9	15.4	13.4	11.7	17.7
1997	16.0	12.8	19.1	19.4	19.5	20.6	20.1	20.3	20.1	18.7	18.6	14.4	18.3
1998	18.1	19.6	20.1	20.4	21.2	23.2	21.4	19.9	20.3	17.8	12.6	10.0	18.7
1999	14.1	14.8	18.9	18.7	19.5	21.1	18.9	19.2	19.6	17.6	12.6	12.0	17.3
2000	12.1	12.1	16.5	19.3	20.7	22.4	19.8	19.7	19.7	16.9	14.7	12.7	17.2
2001	13.5	14.9	19.0	18.2	21.0	22.2	20.0	20.1	18.6	17.9	13.9	14.3	17.8
2002	16.6	15.7	20.1	20.0	20.5	22.3	21.8	20.0	19.1	17.7	14.4	18.0	18.8
2003	16.0	17.1	19.3	20.5	19.2	21.2	20.4	19.6	20.0	16.3	16.0	14.0	18.3
2004	18.2	15.4	16.1	19.3	18.3	21.9	20.3	20.6	19.9	16.7	15.5	15.8	18.2
2005	15.4	15.7	19.3	18.6	20.3	21.7	20.3	20.2	20.9	16.2	14.5	10.5	17.8
2006	15.7	18.2	17.8	19.3	19.3	22.2	20.6	20.5	20.2	18.8	15.6	16.2	18.7
2007	16.7	17.9	17.3	19.3	21.8	22.4	20.7	19.6	20.3	15.6	14.7	10.5	18.1
2008	14.1	14.3	13.3	18.9	20.2	21.4	20.0	19.8	20.3	16.6	13.8	11.0	17.0
2009	13.5	16.0	17.9	19.4	19.4	21.7	20.9	20.3	20.0	17.5	14.0	18.1	18.2
2010	15.2	18.3	18.0	20.5	21.6	22.5	20.9	20.5	19.7	15.9	14.7	12.1	18.3
2011	14.6	15.9	16.3	20.6	20.8	21.2	20.9	20.0	20.4	14.7	16.8	11.5	17.8
2012	13.3	14.0	16.1	20.7	19.4	22.2	19.8	19.6	19.9	14.5	14.3	13.8	17.3
Mean	14.5	16.0	18.0	19.1	19.4	21.5	20.3	19.7	19.3	16.2	14.1	13.1	17.6

Appendix Table 6: Mean monthly climatic parameters

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual/ Average
Rainfall (mm)													
Nura Era	45.2	7.5	60.6	43.0	27.9	34.0	111.0	137.6	46.3	50.9	8.6	10.5	583.1
Metahara	11.97	5.24	59	39	25.7	23	124	120.6	31.4	34	4.91	4.79	483.6
Temperature (^{0}c)													
Nura Era	22.0	22.7	24.8	26	27	28	25.5	25.17	25.4	24	21.4	20.9	24.3
Metahara	23.5	24.4	26.6	27	28.4	29	26.7	26.2	27.1	25	23.4	22.2	25.9
Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual/ Average
Humidity (%)													
Nura Era	40.2	32	39.4	39	30.6	34	38.2	48.6	48.4	32	32.8	37.4	37.7
Metahara	39.2	32.3	37.9	40	35.7	35	43.5	49.1	45.2	37	33.8	35.7	38.6
Sunshine duration (hrs)													
Nura Era	8.8	9.6	7.95	8.4	9.4	5.4	6.7	7	7.5	8.3	9.5	9.5	8.2
Metahara	8.8	10.2	8.8	8.8	9.2	8.8	7.3	7.3	7.9	8.8	9.7	9.8	8.8
Wind speed (m/sec)													
Nura Era	1.4	1.5	1.5	1.5	1.8	2.7	2.9	2.2	1.6	1.3	1.4	1.4	1.8
Metahara	1.6	1.7	1.7	1.5	1.5	2	2.2	1.7	1.4	1.3	1.4	1.5	1.6