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Irrigation Practices in Ethiopia: Characteristics of Selected Irrigation Schemes

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International Water Management Institute

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Contents

Acronyms and Abbreviations

ADA	Austrian Development Agency
CSA	Central Statistical Authority
EEC	European Economic Commission
ESISC	Ethiopian Sugar Industry Support Center
ETMC	Ethiopia Tobacco and Matches Corporation
EWRDA	Ethiopian Water Resource Development Authority
GOE	Government of Ethiopia
HVA	Hangler Vondr Amsterdam
IDA	International Development Association (World Bank)
IWMI	International Water Management Institute
LWF	Lutheran World Foundation
MAADE	Middle Awash Agricultural Development Enterprise
PADEP	Peasant Agricultural Development Program
UAAIE	Upper Awash Agro-Industry Enterprise
UNDP	United Nations Development Programme
WUA	Water User Association
WC	Water Committee

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Besides the field survey, secondary information for this report were taken from the M.Sc. theses conducted on the selected irrigation schemes, particularly on Hare, Sile, Meki-Ziway, Bilate, and Upper Awash, with the support of the "Impact of Irrigation on Poverty and Environment" project of IWMI. Other sources of information for the report were appraisal of small-scale irrigation schemes in the Indris watershed, and leaflets published by Metahara and Wonji-Shoa sugar estates and Middle Awash Agricultural Development Enterprise.

Finally, we are very grateful to the Austrian Development Agency (ADA) and its staff members for providing us the opportunity to carry out this work (fieldwork, preparation and compilation of this report). We hope that the report and accompanying outputs will be useful to the ADA and to others considering investment in agricultural water development in Ethiopia in particular, and in sub-Saharan Africa in general.

Foreword

This report is prepared based on a collaborative research project titled "Impact of Irrigation on Poverty and Environment". The project is sponsored by the Austrian Government and the Austrian Development Agency (ADA) to be executed by the International Water Management Institute (IWMI) and Institut für Ökologischen Landbau (IfÖL), Universität für Bodenkultur Wien (BOKU), Austria, in collaboration with other Ethiopian and Austrian Institutions.

The overall project focuses on understanding the crucial role that water, in conjunction with other factors, needs to play to reduce poverty and food insecurity, while maintaining an environmental balance. Thus, the research promotes irrigation development that will enhance positive impacts such as poverty alleviation and minimize negative impacts such as environmental degradation. Gaining a clear understanding of the impacts of past investments in irrigation is an essential prerequisite for improving future interventions. The research project is carried out in Ethiopia. It will, therefore, have special relevance to Ethiopia, but the results will also have substantial generic application. Through IWMI's close partnership with Ethiopian policymakers, the project can potentially have a major impact in the country. The results will also be broadly disseminated to the water/ agricultural policy and development communities to inform and influence the thinking on approaches to irrigation development. This research will conduct a comprehensive assessment of socioeconomic and environmental impacts of irrigation investments in the selected sites through the networks of project partners, and links to other local and international research and development initiatives.

The project implementation is based on undertaking a broad assessment at the national level, a detailed case study at selected irrigation sites and drawing synthesis and lessons learnt to be applicable to other sites. The primary objective of this report is to provide pertinent and general information about all the selected sites. It is believed that this report will guide researchers to quickly identify key issues pertinent to a detailed investigation of a particular aspect that attracts special investigations.

In this report, documentation and information for 12 irrigation systems totaling about 22 sites/ schemes have been identified. The common characteristics of these schemes have been provided in this report, with a view of having comprehensive information for the case study sites that are investigated under this project. Another working paper, related to this project, also provides a database according to irrigation typology, and readers interested in the overall irrigation development in Ethiopia are advised to refer to this material by Awulachew et al. (2007).

In order to identify these case study sites, criteria were developed at the initial phase of the project. The criteria that were used include:

- Should be within the five focal basins. These are: Blue Nile, Awash, Rift Valley, Tekeze and Wabe Shebale (Hararge Highlands)

- Should include the various schemes classified based on typologies: Large/medium-scale schemes, small-scale modern and traditional schemes

- Should be accessible, and if possible should be situated close to one of the collaborating institutions

- Should cover various cropping patterns as much as possible
- The overall selection should consider regionality and agroecology as much as possible
- Create synergies with other existing projects

Accordingly, the following sites were identified.

Table 1. Large and medium-scale schemes (8 enterprises/systems, 10 schemes).

Name of scheme	River basin	Major crop(s)	Agroecology	Region	Remark
Middle Awash Agricultural Development Enterprise	Middle Awash	Mixed	Kolla	Afar	
Wonji-Shoa Sugar Estate	Awash	Sugarcane	Woyna Dega	Oromia	Outgrowers
Metahara Sugar Estate	Awash	Sugarcane	Kolla	Afar	Outgrowers
Upper Awash Agro-Industry Enterprise	Upper Awash	Mixed	Woyna Dega	Oromia	Tibila, Merti Jeju, Nura Era
Finchaa Sugar Estate	Nile	Sugarcane	Woyna Dega	Oromia	
Sile Irrigation Scheme	Rift Valley	Mixed	Kolla	SNNPR	
Bilate Irrigation Scheme	Rift Valley	Mixed	Kolla	SNNPR	
Meki-Ziway Irrigation Scheme	Rift Valley	Mixed	Woyna Dega	Oromia	

Note: SNNPR - Southern Nations, Nationalities, and People's Region

Table 2. Small-scale schemes (2 systems of 10 sites, 2 independent sites, total 12 sites).

Name of scheme	River basin	Major crop(s)	Agroecology	Region	Remark
Wedecha-Belbela Irrigation System (4 modern + 3 traditional)	Awash	Mixed	Dega	Oromia	System of schemes
Hare Irrigation Scheme	Rift Valley	Mixed	Kolla	SNNPR	
Indris Irrigation Scheme (2 modern + 1 traditional)	Blue Nile	Mixed	Woyna Dega	Oromia	System of schemes
Golgota Irrigation Scheme	Awash	Mixed	Woyna Dega	Oromia	

Note: SNNPR - Southern Nations, Nationalities, and People's Region

This report, therefore, provides detailed information on these selected case study sites based on rapid appraisal, secondary data and site visits. In addition, there are also additional sites that are used in the project, which include Timbel and Tikurit in the Blue Nile Basin, Hararge Highlands (2 sites) and Tekeze Basin (2 sites). There are also more sites that are used by M.Sc. and Ph.D. students sponsored under this project.

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September 2007

MIDDLE AWASH AGRICULTURAL DEVELOPMENT ENTERPRISE

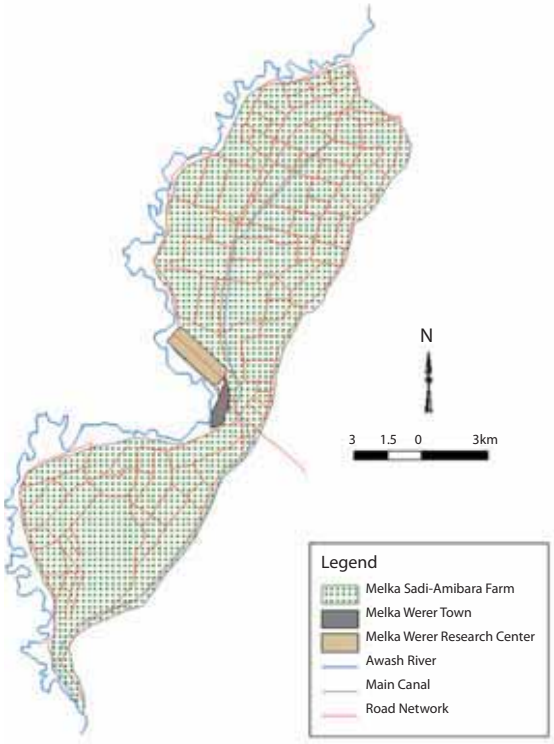
Table 3. Profile of Middle Awash Agricultural Development Enterprise.

Location	9°12'8" to 9°27'46" N
	40°5'41" to 40°15'21" N
Year of establishment	1984
Scheme type	Government, but a significant portion of the scheme given to private investors
Water source	Awash River
Diversion type	Concrete weir
Irrigated area (ha)	
Designed	14,600
Currently irrigated	6,569
Crops	
Major	Cotton
Minor	Banana, pasture and cereals
Number of employees	6,975

Location

Middle Awash Agricultural Development Enterprise is located within the Ethiopian Rift Valley in the Middle Awash, adjacent to the Awash-Mille highway, 265 kilometers (km) away from Addis Ababa as shown in figure 1.

Figure 1. Melka Sadi-Amibara Irrigation Schemes.



Historical Background

The area was first identified for large-scale irrigation development when the UNDP contracted Sogreach to study the whole Awash Basin in 1964. The study identified Melka Sadi and Amibara areas as potential sites for irrigation development. A feasibility study was completed in 1969 and detailed soil surveys were conducted in 1971. Following this, the IDA of the World Bank appraised the development of a state farm with an area of 14,600 hectares (ha) in the Middle Awash. Construction work began in 1978 and was completed in 1984 entirely by Ethiopian contractors under the supervision of Sir William Halcrow and Partners and the then Ethiopian Water Resource Development Authority (EWRDA). The first areas of development were irrigated in 1980 and gradually the area was expanded to reach full-scale production in 1984 (MAADE 2006).

The enterprise consists of Melka Sadi, Melka Werer and Sidhafagae farms as well as a factory that is used for cotton processing.

Physical Features

The topography of the enterprise reflects the recent geomorphologic history of the Middle Awash Valley, through which deposits from the Awash River have constructed an extensive alluvial plain (figure 2). The overall slope increases away from Awash River.

Ground elevation is approximately 750 meters (m) in the west, which ascends gradually to the eastern part. Gradients are generally very low, predominantly lying in the range of 1-2 percent.

The soils of the area include sandy loam, loam, silt and clay loam where silt dominates the larger portion of the area (Belayneh 2005). Clay content in the Middle Awash area is 40-84 percent with an available soil moisture content of 180-250 millimeters per meter (mm/m).

Figure 2. A typical view of the Middle Awash Valley.

The climate is semi-arid with a bimodal rainfall of 533 millimeters (mm) annually. The long rainy season occurring from July to September accounts for 49 percent of this rainfall (264 mm) and the short rainy season from February to April (156 mm) accounts for 29 percent. The rainfall pattern is characterized by inter-seasonal and inter-annual variations. The mean minimum temperature is 15.2^{O}C in December and 23^{O}C in June, while the mean maximum temperature is 32.5^{O}C in December and 38^{O}C in June. Mean relative humidity is lowest in June at 36 percent and highest in August at 58 percent. The average daily sunshine hours is 8.5 with an average solar radiation of 536 calories per square centimeter per day (cal/cm^2/day).

The then Amibara irrigation project was appraised to irrigate a total area of 14,600 hectares in the Melka Sadi and Amibara plains. However, when the project was started the government leased 4,600 hectares of land to private developers and the area of the project was reduced to 10,000 ha. Furthermore, in the early 1990s another portion of the irrigated land was given to the local people and private investors; some parts of the area were abandoned due to salinity, as a result, at present (2007), the total irrigated area of the state farm has declined to 6,569 hectares.

Employment Contribution

Before the establishment of the irrigation project, the area was sparsely inhabited by indigenous Afar people. But, as irrigated agriculture demands much labor, influxes of migrant laborers were attracted from the surrounding highlands and boosted the population size of the area to 40,175 in 1996. Recently (in 2006), the total number of employees working in the enterprise was 6,975, out of which 920 were permanent, 75 were contract workers and the remaining 5,980 were temporary employees.

Irrigation Water Source and Management

Irrigation water for the project is diverted from the Awash River. Diversion is achieved by means of a 100 meter long rock fill weir across the river. The weir is designed for a flow of 700 cubic meters per second (m^3/s) with design discharge of 13 m^3/s at the head works of the canal.

The main canal runs 26 km from the diversion weir up to the Melka Werer Farm, which is now mostly cultivated by private farmers (figure 3). The distribution and drainage system is using unlined canals with major control structures in reinforced concrete and minor structures in masonry (figure 4). Offtakes from the primary canal provide irrigation water to the MAADE in Melka Sadi, and to the Melka Werer Research Station and Amibara Settlement Farm in the Amibara area. These gravity supplies were first provided in 1980 and replaced the original pumped supplies from the river.

The project area is protected from flooding, both from the Awash River and from the adjacent hillside catchments, by a series of earth dykes.

Irrigation water in the scheme is applied using furrow, border and basin irrigation methods, while the furrow irrigation technique using siphons is widely practiced. The furrow length ranges from 200 to 250 m with furrow spacing of 0.9 m. In recent operations, furrow lengths are reduced by constructing small soil bunds within furrows to control irrigation water due to the problem of land leveling.

Figure 3. The main canal that serves Melka Sadi and Amibara irrigation schemes.

Agricultural Production

MAADE is major large-scale producer of cotton lint, oilseed and planting seed in the country. The major crop cultivated in the enterprise is cotton while banana, groundnut, sesame, pasture, cereals and vegetables are growing in limited areas (figures 5 and 6).

The yields of cotton achieved in the enterprise is 3.5 tons per hectare (t/ha). Acala Sj-2, Gedera-236 and Deltapine-90 are the major cotton varieties currently in use in the enterprise. Land preparation for cotton production starts in mid-January followed by planting in early April, and cotton is harvested by handpicking in September every year. After cotton is harvested twice, the area is left open to the surrounding pastoralists to be used as grazing land.

Due to the favorable climate, altitude and better management of cotton lint, the strength of the fiber and quality of cotton produced in the enterprise is of high quality thereby achieving world standards. The staple length ranges from $1^{1}/_{4}$–$1^{1}/_{6}$ inches whereas the grade ranges from middling to good middling and its micronaire value is between 3.2 and 4.2. The cotton lint is free from honeydew and as a result the cotton lint is flawless and spotless.

Socioeconomics

The project makes an important contribution to the country's economy through import substitution and foreign exchange earnings. The current production of cotton ranges from 4,500 to 7,200 tons of cotton lint, 9,000 to 120,000 tons of cotton oilseed and 300 tons of cotton planting seed per year.

Figure 4. Conveyance structures at MAADE, (a) Irrigation water passing above a drainage canal; (b) the drainage water after it passed under the irrigation canal.

(a)

(b)

Figure 5. Large-scale cotton production in the Middle Awash Valley.

Figure 6. Chemical spraying for crop protection in the Middle Awash Valley.

Infrastructure works include a network of gravel surfaced service roads and staff housing, buildings and services at the project control center and at the MAADE. A project control center, which is responsible for the operation, maintenance and replacement of project components up to the secondary canal level, is also equipped with vehicles, and construction and maintenance equipment. There is also the provision of water supply from boreholes in the farm villages.

Environmental Impact

Salinity and Sodicity/alkalinity are the major problems that resulted in the valley due to irrigation practices in the enterprise. In some places high salinity and sodicity/alkalinity levels coupled with poor drainage of the soils are at present resulting in quite a large area of productive lands being abandoned from cultivation. Over 2,000 ha of the Melka Sedi-Amibara State Farm that was cultivated for bananas for about 16 years (1971-1986), and other areas that were cultivated for cotton recently (1982-1992), have gone out of cultivation due to these problems.

The other environmental impact, that is usually associated with the establishment of the enterprise, is the introduction and invasion of a thorny shrub by the name of *Prosopis julifora* in the Middle Awash Valley (figure 7). The plant/weed covers most of the area near the enterprise, which was once barren land during dry seasons and possibly used for grazing purposes during wet seasons. Even if it has some benefits in reducing wind erosion and increasing the organic matter content of the soil, it created problems both to the enterprise and the surrounding inhabitants as it affects the canal network of the farms and cannot be used as animal feed.

Figure 7. Prosopis juilfora *is creating problems for the enterprise by invading the canal network of the irrigated fields.*

WONJI-SHOA SUGAR ESTATE

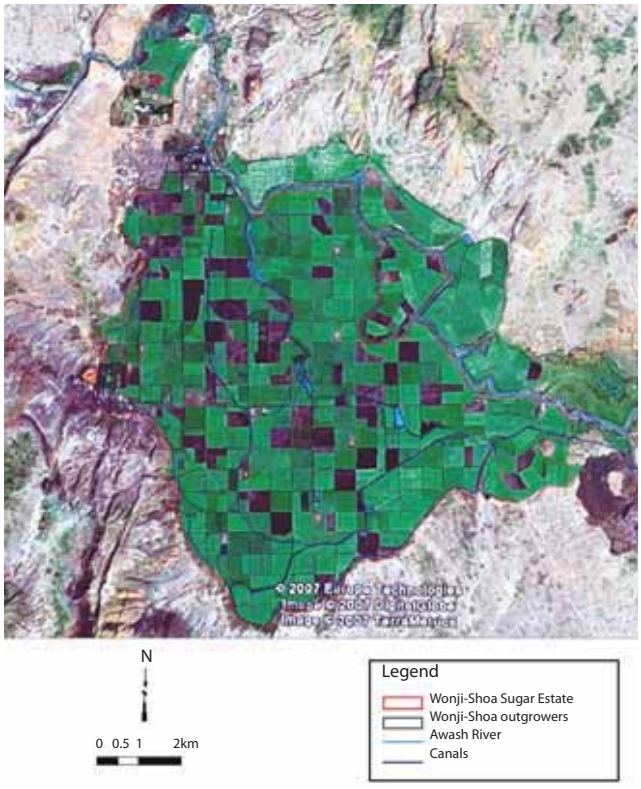
Table 4. Profile of Wonji-Shoa Sugar Estate.

Location	8°21' to 8°29' N 39°12' to 39°18' E
Year of establishment	1954
Scheme type	Government
Water source	Awash River
Diversion type	Pumping station
Irrigated area (ha)	7,279.8
Crops	
Major	Sugarcane
Minor	Haricot bean, Crotalaria
Number of employees	7,500

Location

The Wonji–Shoa Sugar Estate lies downstream of the Koka Dam in the Central Rift Valley of Ethiopia in the Awash River Basin, 110 km southeast of Addis Ababa and 10 km south of Nazareth by road as shown in figure 8.

Figure 8. Wonji-Shoa Sugar Estate and its out-growers.



Source: http ://earth.google.com

Historical Background

Before the establishment of the estate the Wonji Plain was a sparsely populated area due to flood hazard of Awash River and Malaria infestation. On this plain a Dutch holding company, HVA, was granted a concession of 5,000 ha of land for the establishment of a sugar estate and factory. On March 20, 1954, the Wonji Factory was inaugurated and started producing the first bags of Ethiopian sugar. Because of the increasing demand for sugar in Ethiopia the Wonji Estate expanded itself and included an additional 1,600 ha of land at Shoa, which is within a 7 km distance from Wonji, and the Shoa factory started production of sugar in 1962. The Wonji Irrigation Scheme is considered as the first commercial large-scale irrigation project in Ethiopia (WSSF 2006).

Physical Features

The Wonji-Shoa Irrigation Scheme is found at an altitude of approximately 1,500 meters above sea level (m.a.s.l.). In the estate, generally, the slope of the farm is very gentle and regular. More than 50 percent of the farm is heavy clay soil and the rest is light soil. It has a semi-arid climate and receives an average annual rainfall of 831.2 mm, peak daily evapotranspiration of 4.5 mm, mean annual maximum and minimum temperatures of 27.6^0C and 15.2^0C, respectively. The total concession area of the estate is 6,162.8 hectares, of which 5,905.13 hectares are under cultivation, while 257 ha are occupied for canals, roads, living quarters, etc. Out-growers irrigate an additional area of 1,117 ha of land.

Employment Contribution

The Wonji Plain, which was not inhabited five decades ago, now has more than 4,000 regular employees and their dependants. This number rises well over 7,500 during the milling season. The Wonji-Shoa and plantation community as a whole, i.e., employees, their families and residents within the concession area, is about 30,000.

Irrigation Water Source and Management

Water is pumped from Awash River through a pumping station at Wonji (figure 9) and almost the entire estate is fed from this pumping station through an extensive earthen canal system and storage facilities. Pumps run continuously to store water in reservoirs, which are spread at various locations in the estate, and the estate is irrigated partly from the water supplied directly by the pumps and the rest from the reservoirs. There are seven main, and twelve, tertiary night storage reservoirs in the estate.

The water delivery infrastructure is all open canals. The main canal is 480 m in length and the secondary canals are classified as very big (40,492 m) and big (36,627 m). Tertiary canals are classified into medium (113,929 m) and small (84,060 m). The type of water control equipment is fixed proportion division and manual gate (figure 10). The water control equipment is located at the primary and secondary levels, and some are located at tertiary level. The location of discharge measurement facilities is at primary canal level, but there are also measuring devices in the fields. Calibrated gates are employed for discharge measurement purposes (ESISC 2000).

Figure 9. The main pump station at Wonji has eight pumps with design discharge of 55,000 liters per second (l/sec).

Blocked-end furrow irrigation system is used to irrigate sugarcane fields in the estate as well as in the farms of the out-growers (figure 11). Water applied to each furrow is cutoff as it reaches the end of the furrow, which is blocked and ponds up within the furrow. The furrow length depends on the gradients of the different farms and three lengths 32 m, 48 m and 64 m are being used.

Irrigation is practiced through an extensive network of irrigation and drainage canals, of which the total length is 300 and 200 km, respectively. Irrigation application volume and intervals vary according to the type of the soil in the scheme. The gross irrigation depth ranges from 165 to 215 mm whereas the irrigation interval varies from 10 days for light soil to 28 days for heavy soil.

The hand feel or finger test method is used to recognize the need for irrigation. In each farm there is a history card in which the date of irrigation is recorded. A test is conducted at two depths (30 and 60 cm) a few days before the expected date of irrigation, and irrigation is scheduled when the test results indicate dry soil.

Agricultural Production

The main crops cultivated are sugarcane, haricot bean and crotalaria. Sugarcane is planted at a rate of 16-18 t/ha in the estate. Fallowing is practiced using Crotalaria as fallow crop for about nine months (figure 12).

Mechanical tillage is used for tillage operations in the estate. Mechanization is also used for other farm operations like cultivation, cane loading and cane haulage.

Figure 10. A silting basin at Wonji is employed to remove sediments from the diverted Awash River.

Figure 11. Furrows are used to apply irrigation water in the farms.

Figure 12. Large-scale sugarcane plantation at Wonji-Shoa.

Socioeconomics

The Wonji and Shoa sugar factories run under one management, the Wonji-Shoa Factory, which is a public enterprise. The Wonji confectionery can produce up to 700 tons of the popular retail packed sugar and can also prepare up to 2,400 tons of Desta Sweets per year for the market. Molasses and baggasse are two of the by-products of the processing factory which are marketable. Molasses is mostly sold to local distilleries as well as to farmers in the vicinity to be used as animal feed. Bagasse, on the other hand, is wholly used as fuel for the boilers of the factory to generate electricity, which is used by the factory itself and the community, and to produce steam, which is used to run the mills and for boiling purposes in the course of sugar production. There are seven farmer cooperatives surrounding the enterprise that cultivate and sell sugarcane to the enterprise as out-growers. The enterprise gives technical advice to these out-growers through its out-grower department.

The estate provides houses for permanent as well as seasonal workers in 17 villages which are spread all over the compound. The estate also has a 176 bed hospital, 2 polyclinics and provides free medical services to the employees and their families, and to the surrounding community. It also has one high school and four elementary schools in addition to the small schools in the villages at the plantation. Social clubs (figure 13), sports fields, a swimming pool and cinema hall with facilities are also available within the enterprise.

Figure 13. One of the recreational centers in Wonji-Shoa.

Environmental Impact

One of the positive environmental impacts brought about by the irrigation project is the creation of a better microclimate in the project area. The Wonji-Shoa Estate, unlike other areas in its vicinity, is green all year-round and has a cool microclimate. As shown in figure 8 there is a clear contrast between the irrigated and surrounding area. However, there is a problem of a shallow groundwater table due to improper irrigation practices in some parts of the estate which might create salinity problems.

METAHARA SUGAR ESTATE

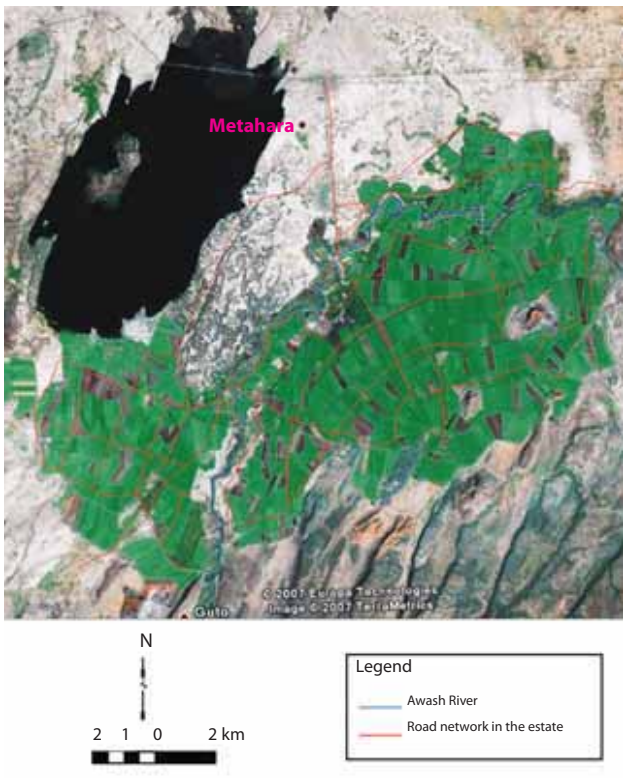
Table 5. Profile of Metahara Sugar Estate.

Location	8°21' to 8°29' N 39°12' to 39°18' E
Year of establishment	1965
Scheme type	Government
Water source	Awash River
Diversion type	Concrete and gabion weir
Irrigated area (ha)	11,058
Crops	
Major	Sugarcane
Minor	
Number of employees	11,000

Location

Metahara Sugar Factory is located about 200 km southeast of the capital city Addis Ababa, on the Addis Ababa-Dire Dawa-Djibouti road within the Upper Awash Valley as shown in figure 14.

Figure 14. Metahara Sugar Estate.



Historical Background

The establishment date of the Metahara Sugar Factory goes back as far as 1965, the time when the Dutch company, named as Hangler Vondr Amsterdam (HVA) had surveyed the area for sisal development. The increasing demand for sugar in Ethiopia and the suitability of the land and climate for sugarcane cultivation attracted HVA to extend the sugar industry to the Metahara Plains. As a result in July 1965 an agreement was signed between the Ethiopian Government and HVA under which the company acquired a concession of 11,000 ha of land. Subsequent to the signing of the agreement, sugarcane cultivation was started in 1966. The factory started producing plantation white sugar on November 9, 1969 with an initial crushing capacity of 1,700 tons of cane per day (TCD). Since then, the factory had undergone successive phases of expansion. The first expansion was made in 1973 to raise the crushing capacity of the factory to 2,450 TCD. The enterprise was nationalized in 1975 and organized under the Ethiopian Sugar Corporation. The second and third phases of expansion took place in 1976 and 1981, which raised crushing capacity to 3,000 and 5,000 TCD, respectively (MSF 2005).

Physical Features

Metahara, with an altitude of 950 meters above sea level, has a semi-arid climatic condition and the average annual rainfall is 543 mm. The average pan evaporation is 6.9 mm. The maximum and minimum relative humidity is 85.4 and 30.3 percent, respectively. The mean annual maximum and minimum temperatures are 32.8°C and 17.5°C, respectively. The hottest period of the year extends from March to June whereas the coldest period extends from September to January. The soil type ranges from sands to clay loam. Most of the plains in Metahara are gentle and suitable for gravity irrigation; hence, more than 81 percent of the farm is irrigated by gravity. The Enterprise currently has a total concession area of 14,733 hectares, out of which about 10,300 hectares is covered with sugarcane plantation. The total design area of the scheme is 10,358 ha (figure 15).

Employment Contribution

All employees live within the concession area in the main compound near the headquarters and seven camps located at convenient places within the plantation. The estate provides free housing, water and electricity to its employees. The workforce includes professionals, semiprofessionals, clericals and manual laborers. At peak time the workforce reaches 11,000 where 3,700 are permanent employees and the remaining are seasonal workers. The total population of the enterprise consisting of employees and their families is estimated at 35,000.

Irrigation Water Source and Management

Irrigation water is abstracted from the Awash River via two diversion weirs and intake headworks found at Metahara and Abadir (figure 16). The method of water abstraction is gravity diversion. The main intake at Metahara is made of concrete and is controlled and regulated by the state itself. However, the diversion structure at Abadir is made of gabion and is managed by the Ministry of Water Resources.

Figure 15. Typical view of Metahara Sugar Estate.

There are 23 reservoirs for irrigation water storage, where the water holding capacity ranges from 6,500 to 93,000 cubic meters (m^3). More than 1,200 km of canal network supplies irrigation water to sugarcane fields, predominantly using the gravity system with night storage reservoirs balancing out day and night irrigation flows.

The water delivery infrastructure consists mostly of unlined canals but with some lined canals in particular areas of the estate (figure 17). Manual gates are used to control irrigation water. Water control structures are found at primary, secondary and tertiary levels. Calibrated sections and gates are employed to measure water discharge.

Furrow irrigation using plastic siphons, typically of 70 mm internal diameter giving approximately 5 liters per second (l/sec) flow at 300 mm head, has been in use for a long time. Recently, a 425 mm plastic fluming (hydroflume) has been introduced to use as an alternative to feeder ditches and siphons (figure 18).

A three-man irrigator team is responsible for accommodating the 200 l/sec lead stream and 40 siphon tubes. Irrigation interval depends on the soil types of the estate and varies from 7 days for sands to 22 days for clay loam. The application rate also varies in a similar way from less than 550 m^3/ha for sands to more than 1,500 m^3/ha for clay loam.

Canal maintenance is usually done using human labor but the main canal is usually maintained using an excavator.

Figure 16. A concrete intake at Metahara near Awash River.

Figure 17. Canals made of stone masonry and inclined plane are used to supply irrigation water to the field.

Figure 18. Recently, hydroflume has been introduced to replace feeder canals and siphons.

Agricultural Production

The main crop cultivated is sugarcane and there is also some fruit cultivation (figure 19). About 11 commercial and semi-commercial sugarcane varieties are in use by the enterprise, which are selected based on compatibility to the soil characteristics of the area and their ability to resist prevalent diseases.

Planting of sugarcane is usually practiced from mid-October to the end of June in a particular year (figure 20). Tillage operations such as subsoiling, plowing, harrowing, ridging and furrowing are conducted before planting cane sets.

The average land productivity is about 165 tons of cane per hectare, which makes the enterprise one of the highest cane producing farms in the world. About 1,091,100 tons of cane is supplied to the factory annually. Along with the cane plantation, the enterprise owns 140 ha of land covered with various types of fruits such as oranges, mangoes, lemons, grapefruits, etc. About 3,000 tons of fruits are produced annually.

The most widely used fertilizer in the estate is ammonium sulfate nitrate (26% N) with the application rates of 300 kilograms per hectare (kg/ha) for planting sugarcane, 500 kg/ha for the second and third cuttings and 650 kg/ha for the fourth and subsequent cuttings. Insecticides such as Dienone (3 liters per hectare (l/ha)) and Basudin 600 Emulsifiable Concentrate (EC) (3 l/ha) as well as herbicides such as 2-4 D Amine (3 l/ha), Gesapax Combi 500 EC (6 l/ha) and Roundup (5 l/ha) are used to protect sugarcane from insects, diseases and weeds.

Figure 19. Sugarcane cultivation at Metahara Sugar Estate.

Figure 20. Planting of sugarcane sets at Metahara Sugar Estate on newly developed land.

Socioeconomics

The Metahara Sugar Estate is a government managed scheme and is organized into four broad divisions - agricultural operations, factory and logistics, finance and human resources, and support giving and advisory services.

Marketable products of the enterprise are sugar, molasses and various types of fruits. Sugar is supplied to domestic and foreign markets. The annual sales volume stands at 120,000 tons and about 65 percent of the annual sales volume goes to the domestic market while the remaining is exported. Marketing is carried out through the Ethiopian Sugar Industry and the selling price is determined through auction. Tax is paid for land and there is also a charge per volume of water delivered by Awash Basin Authority. On the other hand, the major part of molasses produced, i.e., about 20,000 tons, is exported and a small part of the annual production goes to domestic cattle fatteners and distilleries. Fruits such as oranges, lemons, mangoes and mandarins are subsidiary products of the enterprise. About 3,000 tons of fruit is marketed annually.

A transport link includes all weather roads and a railway that extends into the premises of the company giving easy access for import and export of goods. Other facilities include well built stores, comfortable residential houses, a 60-bed hospital, 2 polyclinics, and 4 satellite clinics. A bank, post office, court and police station are found in the immediate vicinity of the enterprise. Recreational facilities which include cinema halls, sports fields, various clubs and swimming pools are also available in the scheme.

In addition, a vocational school, five elementary schools, seven kindergartens, and a public library are found in the scheme. The enterprise is also equipped with modern communication systems such as telephone lines, internet, satellite television, and short-range radio communications.

Environmental Impact

As compared to the surrounding area the scheme is covered with different kinds of trees, as a result the microclimate of the scheme is improved. On the other hand, there are alkalinity and salinity problems in some parts of the estate, which emanates from improper use of irrigation water and inadequate drainage facilities.

The scheme has also been the subject of repeated investigations by hydrologists and other professionals as it is found near Lake Beseka, which is known for its substantial increase in volume over the past few decades. The estate was also forced to abandon small parcels of its irrigated land due to this problem. One of the potential causes of the rising of the lake could be linked to the irrigation water and requires detailed research.

WEDECHA-BELBELA IRRIGATION SYSTEM

Table 6. Profile of Wedecha-Belbela Irrigation System.

Location	8°46'29" to 8°57'36" N
	38°57'1" to 38°58'58" E
Year of establishment	Early 1980s
Scheme type	Community managed and includes 4 modern and 3 traditional schemes
Water source	Wedecha and Belbela streams
Diversion type	Small earthen dams
Total area (ha)	
Designed	1,600
Currently irrigated	1,300 (some are transferred to flower farms)
Irrigated crops	
Major	Shallot, onion and tomato
Minor	Sugarcane, chickpea and lentil
Number of beneficiaries	1,267 households plus commercial investors

Location

Wedecha-Belbela irrigation schemes are found in East Shewa zone, in the Oromia region near Debre Zeit Town about 52 km from Addis Ababa in the central highlands of Ethiopia (figure 21).

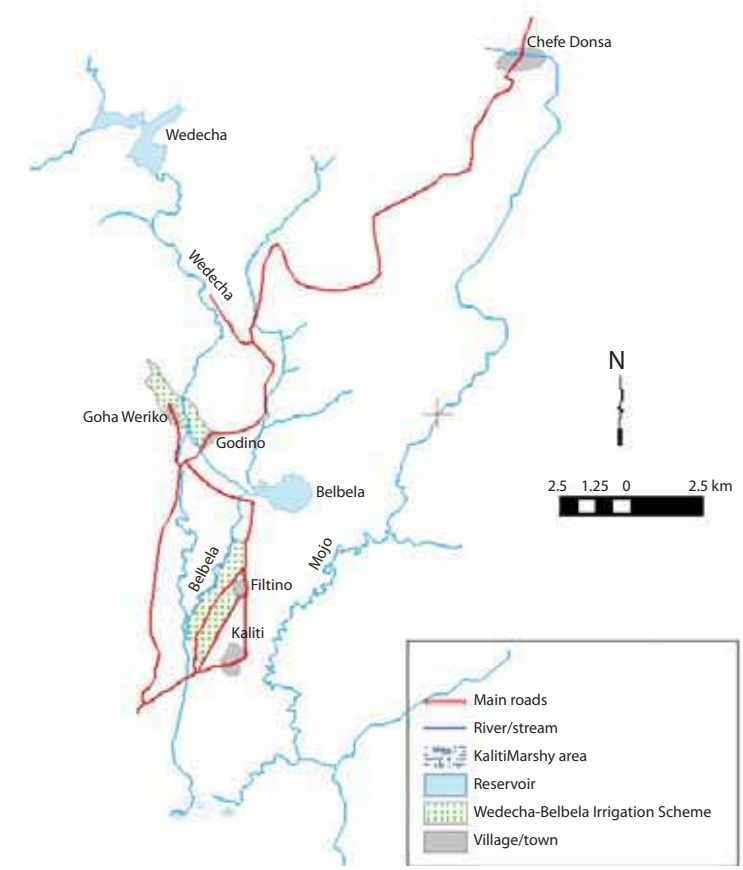
Historical Background

Irrigation in this area has been in practice for many years. Farmers in Goha Weriko village have been practicing traditional irrigation using springwater called 'Goha' over a century ago. In the early 1980s the then Ethiopian Water Resource Development Authority (EWRDA) in collaboration with the Cuban Civil Mission constructed two earthen dams to be used under the previous Ministry of State Farms in an attempt to expand irrigated agriculture in the area. The irrigation infrastructure (canals, protection works and farm structures) were later constructed by the Ethiopian Water Work Construction Authority.

Physical Features

Wedecha-Belbela Irrigation Scheme is found in the central highlands of Ethiopia where the elevation ranges from 1,895 m at the downstream end of the irrigation schemes to 2,437 m at Wedecha Dam site upstream of the schemes. The agroecology is characterized by tepid to cool sub-moist mountains. It has an average annual rainfall of 815 mm with annual average minimum and maximum temperatures of 10.5^{o}C and 25.4^{o}C, respectively. The annual average relative humidity is 53.6 percent with an annual average wind speed of 5.1 kilometers per hour (km/hr). The predominant soil type is Vertisol with some pocket areas covered with light soil.

Figure 21 Wedecha-Belbela Irrigation System.



Employment Contribution

The irrigation schemes in the Wedecha-Belbela Irrigation System serve more than 1,267 households, the largest beneficiary being Goha Weriko with 309 households followed by Godino with 260 households.

Irrigation Water Source and Management

Wedecha-Belbela Irrigation System has two small earthen dams called Wedecha and Belbela. These dams are the sources of irrigation water for seven schemes within four peasant associations (PAs). The schemes are Keteba Gimbi (Keteba PA), Harawa, Goha Weriko, Godino (Godino PA), Fultino, Belbela (Koftu PA) and Denema (Gende Gorba PA).

The water distribution system in the area is of a constant amount. There is an established calendar and each farmer receives irrigation water in their turn without any arrangement on demand. Flooding and furrow irrigation is widely employed to irrigate crops in the irrigation schemes (figure 22). A farmer usually irrigates their field twice a week for crops like tomato and onion during establishment, and once a week thereafter depending on the availability of irrigation water.

Generally, the irrigation water sources is more than sufficient for the schemes but seepage losses in poor primary canals, that use the previous river system in the upper portion (Wedecha Irrigation System), contribute to shortages of water on demand at a given time. Siltation and vegetation growth in the distribution canals also play a significant role by retarding irrigation water flow and hence delaying water delivery in both irrigation systems.

Its pronounced effect is seen in the lower part of the system, in the Belbela irrigation schemes, where farmers are forced to wait for more than eight hours to get irrigation water once it is released from the source. This coupled with poor operation of the system, limited availability of control structures, lack of interest by the farmers to participate in maintenance, and insufficient funds for operation and maintenance are responsible for the poor irrigation water management in the schemes.

Figure 22. Furrow irrigation is widely used in the scheme.

Wedecha Micro-Dam

The Wedecha Micro-dam is found in the upper part of the Wedecha-Belbela Irrigation System (figure 21). During construction its life storage was 14.23 million cubic meters (Mm^3) with a catchment area of 115 square kilometers (km^2). This dam serves five irrigation schemes namely Keteba Gimbi, Harawa, Denema, Goha Weriko and Godino. Two of the five schemes (Goha Weriko and Godino) are beneficiaries of modern diversion structures and they have partially lined canal systems. However, the rest of the schemes practice traditional irrigation by diverting water directly from the main canal. This irrigation system employs the natural waterway for conveyance of irrigation water to the above-mentioned irrigation scheme. This waterway also feeds the leftover water to Belbela Micro-dam, which is found downstream of these schemes.

Belbela Micro-Dam

Belbela Micro-dam is found in the lower part of the irrigation system (figure 23). When constructed its life storage was 11.5 Mm^3 with a catchment area of 85 km^2. The Belbela and Fultino schemes have access to water from this micro-dam using a well-constructed earthen canal system with control structures as modern facilities. The type of water control equipment encompasses fixed proportion division and manually operated gates. Most of the control structures and discharge measurement facilities are found at primary and secondary canal levels.

Figure 23. Belbela Micro-dam.

Agricultural Production

The main farming system in the area is a mixed crop livestock system while horticultural crops (shallot, tomato, potato, sugarcane, cabbage, and onion) cover the largest portion of irrigated agriculture. Pulses like chickpea and lentil are also cultivated using irrigation. Sugarcane is commonly cultivated in the backyards of Goha Weriko and Godino villages. The main rainfed crops in the area include tef, wheat, chickpea, lentil, fenugreek, bean and pea. In this irrigation system multiple cropping is widely practiced. As shown in figure 24, cabbage is especially planted at the borders near the irrigation canals together with shallots (OWRME 1998).

Land preparation is usually carried out using the traditional 'Maresha' using oxen as a source of power for traction. Diammonium Phosphate (DAP) and Urea are the two most commonly used fertilizer in the schemes. Pesticides and insecticides are also widely used for crop protection.

Recently, due to the expansion of flower farming and the horticultural industry in the country there is a huge development and expansion of greenhouses in this irrigation system. An extended area below Belbela Dam, which was once used for surface irrigation, is now converted to chains of greenhouses for flower production. The greenhouses mainly use water from the Belbela Dam and they employ drip irrigation for irrigation (figure 25).

Figure 24. Multiple cropping is a common practice in the Goha Weriko and Godino irrigation schemes.

Socioeconomic

The scheme is jointly managed by the government and local organizations. Oromia Irrigation Authority is responsible for the operation and maintenance of the irrigation system at the dam site, while the water user associations handle the water distribution. Organizations providing various services include Goha Weriko Marketing Cooperative, Yerer Agricultural Development Cooperative, Debre Zeit Agricultural Research Center, and the International Livestock Research Institute.

Most of the time farmers sell their farm outputs to private traders in the local market in Godino village and it is also common to sell the irrigated crop while they are in the field before it is harvested in a wholesale manner through negotiations held between the farmers and the traders. Recently (in 2006) at Goha Weriko, farmers, with the support of Oxfam, organized themselves and established a marketing cooperative. The schemes have relatively good access to both input and output markets as they are near Addis Ababa adjacent to Debre Zeit and also connected by all weather roads. The main institutional constraints include inadequate farmer participation in system operation, management and maintenance, limited technical capacity, poor communication between farmers and the government agencies, inadequate coordination among agencies serving irrigated agriculture, poor state of the physical control structures, inadequate maintenance of the irrigation system, and lack of financial resources for maintenance of the proper functioning of the irrigation facilities.

Figure 25. Belbela Dam also serves greenhouses which are used for the production of horticultural crops for the export market.

Environmental Impact

There is a change in the environment of the villages that use irrigation when compared to the nearby rainfed villages. One of the positive environmental changes is the expansion of vegetation cover such as trees in the immediate vicinity of the irrigators. This, together with the presence of the reservoirs, attracts different kinds of birds and other wild animals (figure 26). The reservoirs and the night storages also serve as a reliable year-round source of water for livestock in the area. Apparently, there is no visible negative impact of this system related to salinity or pollution.

The other environmental concern is the flooding hazard in the rainfed fields downstream of Belbela Dam, which is usually attributed to improper operation of the Wedecha Dam due to defective control structures and lack of a working drainage system. Recently (in 2006), due to high rainfall and low vegetation cover in the catchment areas of the Wedecha and Belbela reservoirs,

Belbela was full and there was an overflow at the tailend of the reservoir, which calls for urgent attention in environmental rehabilitation in the area (figure 27).

Figure 26. Belbela Dam has attracted birds besides its use as a source of irrigation water.

Figure 27. Flooding at the tailend of the Belbela Reservoir due to intense and prolonged rainfall in 2006.

UPPER AWASH AGRO-INDUSTRY ENTERPRISE

Table 7. Profile of Upper Awash Agro-Industry Enterprise.

Location	8°23' to 8°45' N
	39°33' to 39°50' E
Year of establishment	Early 1970s
Scheme type	Government
Water source	Awash River and other streams
Diversion type	Annually maintained sill structures made of loose small sized stones
Total area (ha)	
Designed	7,187
Currently irrigated	5,892
Irrigated crops	
Major	Orange, mandarin, tomato, guava, grape vine, okra, onion, green chilies, cabbage, carrot and beetroot
Minor	Cotton, tobacco, maize, popcorn and beans
Number of employees	15,914

Location

The enterprise is located 174 km away from Addis Ababa along Awash River. Three of its farms and Merti Processing Factory are found in the Oromia region and Aware Melka Farm is found in the Afar region (figure 28).

Historical Background

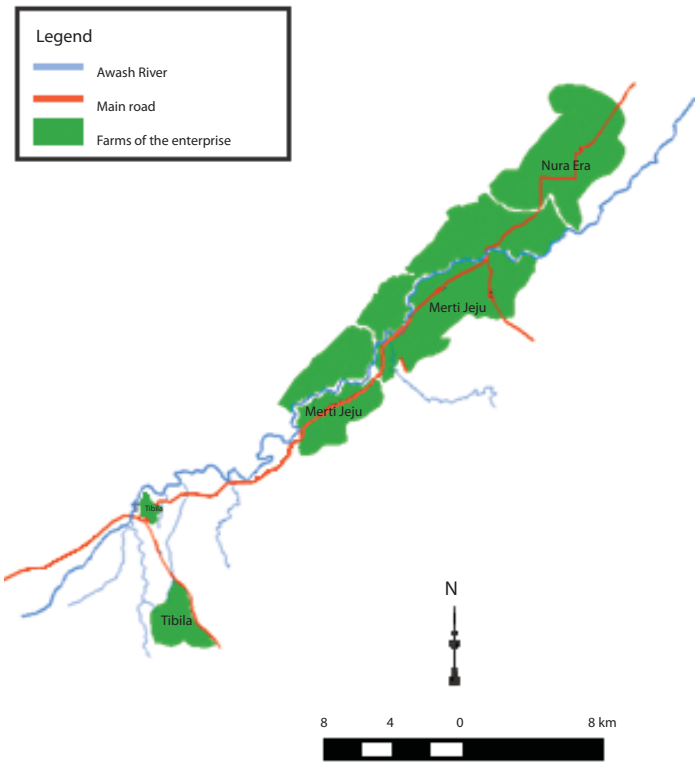
Upper Awash Agro-Industry Enterprise was established when the Government of Ethiopia nationalized all private commercial farms of the country in 1974. In the early and mid-1990s four private farms were merged to form the then Nura Era Agricultural Development Enterprise. With the downfall of the Derg regime in 1986 the enterprise was reorganized and its name changed to Upper Awash Agro-Industry Enterprise (UAAIE 2007).

During the early years of the enterprise most of the area was covered with cotton and tobacco, but with time the area was identified as a potential site for horticulture production and it shifted to the production of high value horticultural crops. Now the enterprise is the number one producer and processor of horticultural crops in the country.

Physical Features

The enterprise is found at an elevation of 750-1,200 m.a.s.l. The average annual rainfall is 500 mm with annual average minimum temperature of 15.3^{O}C and maximum temperature of 32.6^{O}C. The two most important soil types are heavy clay soil and sand loam, of which the pH value ranges from 8.1 to 9.1.

Figure 28. Farms of Upper Awash Agro-Industry Enterprise.



The total area of the enterprise is 7,187 ha. About 6,173 ha of the area can be cultivated through irrigation and 420 ha through rainfed farming. However, due to several reasons, the area under cultivation is about 5,892 ha at present. The enterprise consists of four farms, namely Aware Melka (876 ha), Tibila (1,334 ha), Nura Era (3,277 ha), Merti Jeju (1,700 ha) farms, and the Merti Horticultural Crops Processing Factory.

Employment Contribution

The total number of permanent employees in the enterprise is 1,914. An additional 14,000 temporary and contract employees are hired every year to carry out farming and factory processing. When the family members of the employees are included the total number of the enterprise reaches 37,000.

Irrigation Water Source and Management

The enterprise is mainly a gravity scheme stretching over the two banks of the Awash River, fed by diversion weirs and a pumping station on the Awash River with secondary lifting stations along the canals (Beshir 2005).

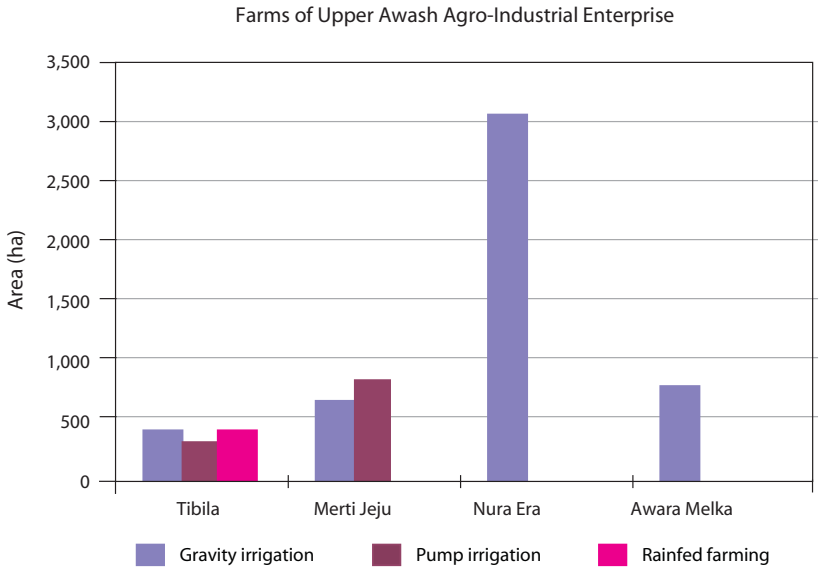
In the upper portion of the enterprise, i.e., Tibila, irrigation water is drawn from Awash River and its tributaries - Wererso and Biskelo - using gravity diversion and a pumping station. In the middle portion, i.e., Merti Jeju, the area is fed by a combination of gravity abstraction, a main pumping station and a secondary lifting station (figure 29). At Nura Era, irrigation water is diverted using gravity sill structure formed by loose small size stones on the Awash River (figure 30). The Nura Era Farm is served by a main canal, which is 32 km in length, and its numerous secondary branches. At about 100 km from the intake there is a regulating structure having four vertical lift gates with a width of 1 m (figure 31).

Next to the regulating structure a concrete canal with a rectangular cross section follows up to the discharge measurement structure.

Furrow and basin irrigation are widely practiced. Basin irrigation is employed to irrigate citrus crops whereas furrow irrigation is used to irrigate row crops such as cotton, maize, tobacco and vegetables. Siphons are employed to supply furrows with irrigation water.

Generally, furrow lengths of 10-30 m are used for small vegetables like onion and tomato, and pulses like green beans, maize and cotton with a furrow spacing of 0.9 m. Irrigation interval in the farm depends on the soil and crop type. For perennial crops it varies between 9-14 days with a total of 24 irrigation applications until maturity, for small vegetables it is in the range of 5 to 8 days with a total of 15-17 irrigation applications and for cotton it is between 10-23 days with a total of 12-14 irrigation applications.

Figure 29. Irrigation and rainfed farming are employed to cultivate crops in UAAIE.



Agricultural Production

The main crops cultivated are fruits (oranges, mandarins, tomatoes, guavas, grape vine), vegetables (okra, onion, green chilies, cabbage, carrot and beetroot), and other crops include cotton, tobacco, maize, popcorn, and beans (figure 32).

Plant spacing commonly used in the farm include 8 m x 6 m for oranges, 7 m x 3.5 m for mandarins, 8 m x 8 m for guavas, 8 m x 8 m for grapefruit and 7 m x 7 m for lemons.

Figure 30. A temporary gabion diversion structure on Awash River diverts water to the Nura Era Farm.

Figure 31. The main intake structure with manually operated gates at Nura Era.

The average yield of tomatoes is 350 quintal per hectare (qt/ha), for oranges is 340 qt/ha, for green beans is 100 qt/ha and, recently, the yield of cotton declined to 15 qt/ha due to disease.

DAP, Urea and Potassium Nitrate are the common fertilizers used in the enterprise. The level of fertilizer used in the enterprise was relatively high in the early 1970s but declined tremendously in the following decades. For example, for oranges it was about 1.69 qt/ha DAP and 12.89 qt/ha Urea, but, recently, this figure declined to 0.11 qt/ha and 0.42 qt/ha for DAP and Urea, respectively.

Pesticides like Suprathion 60% EC, Diaznon, Ridomil Gold, Fetrilion Combi, and Karate 5% EC are widely employed in the enterprise.

Figure 32. Large-scale orange production in Merti Jeju.

Socioeconomic

The enterprise produces fresh as well as factory-processed fruits and vegetables for export and local consumption (figure 33). The major export crops are green (bobby) beans, alium flower, linted cotton and haricot bean seed. It also produces cotton and grapefruits, which are utilized as input in other factories within the country, as well as seeds and seedlings of fruits and vegetables, which are used by farmers and private investors. Recently, the enterprise exported about 3,000 tons of green beans.

Environmental Impact

There is no pronounced environmental impact noticed in the enterprise. This requires a closer look to check if specific salinity or sodicity problems have occurred.

Figure 33. Typical market near Nura Era Irrigation Scheme.

HARE IRRIGATION SCHEME

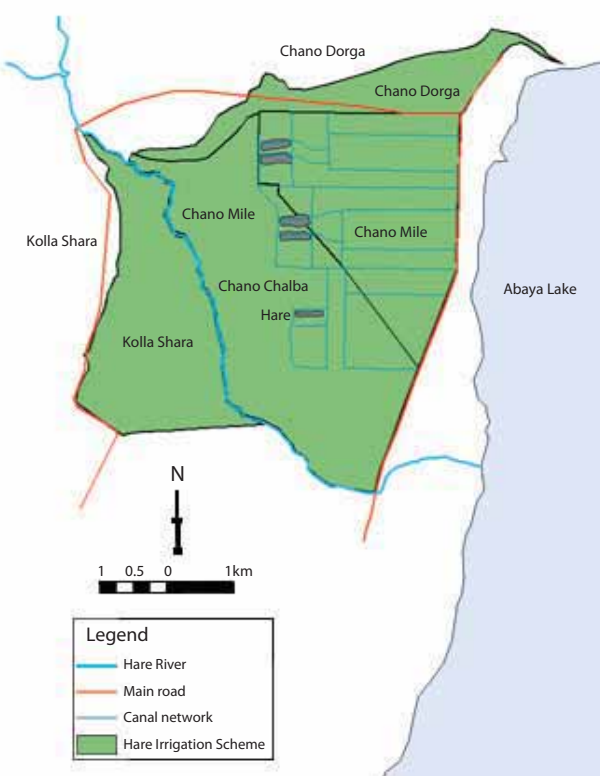
Table 8. Profile of Hare Irrigation Scheme.

Location	6°30' to 6°38' N
	37°33' to 37°37' E
Year of establishment	1993
Scheme type	Community-managed
Water source	Hare River
Diversion type	Traditional diversion and modern concrete weirs
Irrigated area (ha)	2,224
Crops	
Major	Banana
Minor	Mango, cotton, maize, sweet potato and avocado
Number of beneficiaries	19,674

Location

Hare Irrigation Scheme is located in the Gamo Gofa Zone, Southern Nations, Nationalities and People's Regional State at 495 km South of Addis Ababa near Lake Abaya in the Rift Valley Lakes Basin (figure 34).

Figure 34. Hare Irrigation Scheme.



Historical Background

In Hare, traditional irrigation has been in practice for many years. In 1984, the transitional Government of Ethiopia and the China National Complete Plant Import and Export Corporation Limited of the People's Republic of China signed an agreement to establish a modern river diversion scheme on the Hare River. Due to the problem of land acquisition and other reasons, the construction work delayed and the diversion became functional only in February 1996. On the other hand, in 1993 the Lutheran World Federation, with the support of the community, constructed another diversion structure on the Hare River and partially rehabilitated the existing traditional irrigation structures.

Physical Features

The Hare watershed area is found in the western part of the Abaya-Chamo Lake Basin, which is the sub-basin of the Rift Valley lakes. The catchment has a total area of 169 km^2. It is covered by steep mountains with deep and narrow valleys. The plain area that is used for irrigation is found in the lower portion of the basin near the shoreline of Lake Abaya and has a total area of 2,224 hectares (figure 35).

The altitude of the basin varies from 1,200 m.a.s.l near Abaya Lake to 3,480 m.a.s.l in the northwest part of the basin. The average annual rainfall in the irrigated area is 1,309 mm with average annual maximum and minimum temperatures of 30.3^{o}C and 17.3^{o}C, respectively. The soil type in the catchment of Hare River is mainly Acrisol with associated dystric Nitosol whereas in the irrigation field the main soil type is Fluvisol.

Figure 35. Perspective view of catchments of Hare River.

Employment Contribution

According to the local district Census Report in 2006 there are 5,351 households with a total population of 19,674 benefiting from the irrigation schemes. The largest irrigators are found in Chano Mile (about 36%) followed by Chano Chalba (about 26%). The main ethnic group in the study area is Gamo, but there are several immigrants from other parts of the region. About 75 percent of them are registered in the existing farmers' associations (Chano Chalba and Chano Mile).

Irrigation Water Source and Management

Hare River is the source of irrigation water. Two modern diversions and one traditional intake are used to supply water to the irrigation system. Irrigation water is conveyed and distributed using earthen and masonry canals, which have a trapezoidal and rectangular shape (figure 36). The method of irrigation used by the farmers vary, some farmers use furrow irrigation only, others use wild flooding and some use a combination of the two.

The Hare Irrigation System consists of three distinct irrigation schemes based on the location and use of irrigation water (Bassa 2006). The first is the Kolla Shara District that uses irrigation water from the modern diversion with traditional delivery systems at upstream, the second is the Chano Dorga District that uses a traditional diversion and delivery method in the northern part of the system and the third are the Chano Chalba and Chano Mile irrigation schemes which are found in the center of the system near Lake Abaya.

Figure 36. Irrigation structures have other uses beyond water control and delivery in the Hare Irrigation Scheme.

Kolla Shara Irrigation Scheme

Traditional irrigation has been in practice for many years in Kolla Shara. LWF, together with the support of the community, constructed a modern diversion structure with an outlay of 80,000 Ethiopian Birr in an attempt to improve the traditional diversion and irrigation water conveyance in Kolla Shara District. The diversion weir was built from reinforced concrete, which has a width of 2.8 m and height of 1 m (figure 37). Trapezoidal earthen main and secondary canals with a total length of 6 km are used to supply irrigation water to this district. The total irrigated area is 617 hectares.

Figure 37. Modern diversion structure constructed by LWF at Kolla Shara.

Chano Dorga Irrigation Scheme

This is a traditional irrigation system with a total area of 242 hectares. It diverts irrigation water directly from the Hare River to the farm by cutting off a rectangular earthen canal with a width and height of 2.4 m and 1.2 m, respectively, at the bank of the river (figure 38). In this traditional irrigation system there are about 60 outlets from the main canal which are directly employed by the farmers to irrigate the farms without the need for secondary, tertiary and field canals. Because of erosion the bed slope of the traditional canal is not uniform and varies from place to place. At some points it is flat and in other places it is gullies, which have depths of more than 1 m where formed.

Figure 38. Traditional diversion structure at Chano Dorga.

Chano Chalba and Chano Mile Irrigation Schemes

The total irrigated area in this district is 1,365 hectares. A concrete weir constructed by the Chinese, which is located at the middle of the foot of the mountainous escarpment and the irrigation lowland field, is employed to supply irrigation water to this scheme. The weir is 6 m high, 9 m deep and 137 m wide (figure 39). The intake from the weir has a capacity of discharging a maximum of 2.4 m^3/sec. Irrigation water is conveyed to the irrigation fields using rectangular and trapezoidal canals. The turnouts, division boxes, road crossings, drops and the cross regulators are all well constructed with masonry and concrete.

Agricultural Production

Crop production with animal husbandry is the main farming system in the Hare Irrigation system. The main crops grown in the project area are banana, cotton, sweet potato, maize, mango, and avocado (figure 40). The average size of landholdings in the scheme is 0.8 ha. Crop yields differ from district to district in the schemes due to differences in access to irrigation water, soil type, irrigation and crop management. Chano Chalba enjoys the highest average yield with regard to banana (219 qt/ha) followed by Chano Dorga (153 qt/ha) and the smallest productivity is at Kolla Shara (144 qt/ha). Crop productivity varies from 7-22 qt/ha for cotton and 22-29 qt/ha for maize in the irrigation schemes.

Figure 39. A weir constructed by the Chinese, supplies irrigation water to the Chano Chalba and Chano Mile schemes.

Figure 40. Banana is the main crop cultivated in Hare Irrigation Scheme.

Socioeconomic

The Hare Irrigation Scheme is managed by the farming community itself. Water Committees (WCs), which are elected from the irrigators themselves, are responsible for the operation and management of the scheme. The duties of these WCs include scheduling and allocation of irrigation water, assessing and identifying maintenance needs, settling disputes that may arise during the distribution of irrigation water and fining illegal water users according to their bylaws. The number of members in the WCs differ from district to district in the irrigation schemes. The minimum number of members is five at Chano Dorga and the maximum number is eleven at Chano Mile. The WCs usually consist of a chairman, secretary and members, and it is accountable to its District Council.

Cash corps like banana, mango, and cotton are the main marketable products in the schemes. The nearby marketing center for local consumption is Arba Minch Town. Price is mainly determined by negotiations between producers and traders. Sometimes when traders offer a very low price in the local market farmers organize themselves, arrange transport and send their products directly to Addis Ababa through their representatives. As the area is now known for its banana production, farmers are selling their products at reasonable prices and they are good at bargaining prices. Some farmers even started to get involved in the other sectors such as transport, by owning vehicles like minibuses and trucks, from the benefits they gained from their irrigated farms (figure 41).

Figure 41. High value crops have increased farmers' income in Hare Irrigation Schemes.

Environmental Impact

One of the major environmental concerns in the area is the decline in groundwater depth in the scheme, especially near Lake Abaya, which is mainly caused by poor management of irrigation water and lack of working drainage facilities. The other environmental problem is the increasing removal of vegetation cover in the watershed and the resulting high soil erosion and transported sediment. This has also created significant problems in the scheme's irrigation canal network. Siltation of canals is severe, especially at the modern schemes of Chano Mile and Chano Chalba.

FINCHAA SUGAR ESTATE

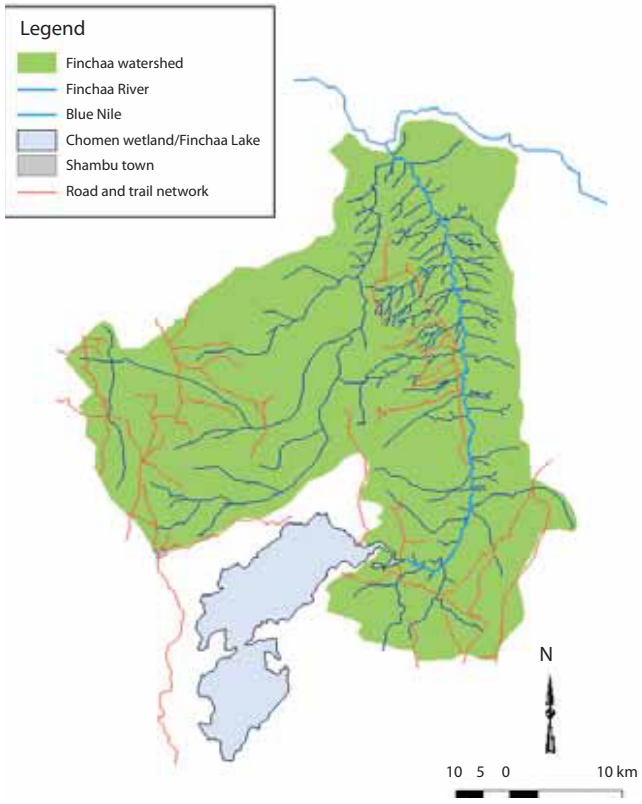
Table 9. Profile of Finchaa Sugar Estate.

Location	9°30' to 9°60' N
	37°10' to 37°30' E
Year of establishment	1998
Scheme type	Government
Water source	Finchaa River
Diversion type	Weir
Irrigated area (ha)	8,500
Crops	
Major	Sugarcane
Minor	Sesame, horticultural crops
Number of employees	6,256

Location

The estate is located in the Oromia Regional State, Eastern Wellega Zone, Horro Guduru District around 350 km Northwest of Addis Ababa (figure 42).

Figure 42. Finchaa Watershed.



Historical Background

In November 1976, the Government of Ethiopia (GOE) commissioned Booker Agriculture International Ltd. (BAI) to undertake a study for identification of potential areas for the expansion of sugar production in Ethiopia. In April 1977, BAI identified Finchaa, Angelele Bolhamo, Gambela, and Amaro, and selected Finchaa Valley as the most suitable site for sugar production. In 1978, the GOE through the Ethiopian Sugar Corporation undertook the task of preparing a complete feasibility study of the Finchaa Valley, which included detailed land and soil capability studies. Construction of the estate was completed in 1998 and production started in 1999 (FSF 1995; Burayu 1995).

Physical Features

The Finchaa Valley bottom is mainly at an elevation of 1,350-1,600 m a.m.s.l and is surrounded by steep escarpment along its southern, eastern and western sides which rise approximately 700-850 m above the valley floor. Finchaa River originates from the Chomen and Finchaa swamps on the highlands. There is a dam at the head of Finchaa Valley for the purpose of storing irrigation water and generating hydroelectric power (Amdihun 2006).

The floor of the valley is dominated by a gently undulating surface with a general slope of 1 to 8 percent northwards. Finchaa River divides the valley into west and east banks. The width of the valley, generally, increases from south to north with an average size of 25-30 km. Many streams join Finchaa River, the main tributaries being Hagamsa, Korke, Fakare, and Boye from the western side and Sargo-Gobana, Aware, Sombo, and Andode from the eastern side (figure 43).

The two major soil types are red to reddish brown friable Luvisols and black heavy clay Vertisols. More than 75 percent of the soil of the irrigated land is Luvisols and the rest is Vertisols. Most of the Luvisols are situated in the middle of the interfluves and have slopes of 2-5 percent. Nineteen percent of the Luvisols are moderately deep. Vertisols is found mostly in the lower areas near the Finchaa River and at the upper ends of the interfluves. This soil is deeper than the Luvisol, going as deep as 120 centimeters (cm).

The scheme has a semi-arid climate with average maximum and minimum monthly temperatures of 30.7^{O}C and 14.8^{O}C, respectively. The average monthly temperature is generally above 18^{O}C. Average annual rainfall reaches 1,300 mm, the main rain being from June to September. Wind speed in Finchaa Valley is low as the surrounding escarpments hinder wind movement. However, wind speed is high between the months of March to June.

Finchaa Sugar Estate has a total irrigated area of 8,500 hectares (in 2007). Out of this 8,286.77 ha is found in the west bank of Finchaa River and the remaining 233.26 is found in the east bank of the river. Currently, the estate is engaged in extending the total irrigated area by 7,000 ha and they also have a plan to expand it further to 20,000 ha in the future.

Figure 43. Topography of Finchaa Valley.

Employment Contribution

There was no significant permanent settlement before the establishment of the estate in the valley. With the exception of a few villages in the southern part, all the villages emerged after the establishment of the estate. Most of the settlers in the valley came from the surrounding highlands or from other regions to work as employees in the estate. According to a CSA report, the total population was 3,391 in 1994 (1,923 males and 1,468 females) and within ten years (1994 to 2004) this figure increased six times in the valley. In the 2004/2005 cropping season the estate had a total labor force of 6,256, of which 1,638 were permanent and the remaining 4,618 were seasonal laborers. Most of the permanent workers are skilled and are assigned to managerial and supervisory duties. Seasonal laborers work in the field and in the factory. Their tasks include planting, weeding, irrigating sugarcane fields, harvesting, and piling of harvested sugarcane. Almost all of the permanent workers are provided free housing, electricity, water and health facilities.

Irrigation Water Source and Management

Irrigation water is diverted from the Finchaa River using a diversion weir and is conveyed to the pump station using a concrete main canal (45 km in length). The water is then pumped to underground aluminium sub–mains, which are more than 340 km long, all over the scheme. Movable sprinklers (semisolid set dragline) are employed for water application in the sugarcane fields (figure 44). These sprinklers manually move from place to place in the farm based on the demand for irrigation. Each sprinkler serves 15 positions on an 18 m X 18 m grid. The laterals are spaced 90 meters and are designed to provide a gross application rate of 134.4 mm per irrigation cycle (i.e., 15-day cycle with a 24-hour set time). The sprinkler assembly comprises 36 m of 25 mm diameter plastic hose, a four meter high galvanized steel tripod, riser valve and a brass sprinkler. The sprinkler is a VYR 35 impact type designed to operate at a pressure of 317 kilopascal (kPa) discharging water through two (2.4 mm X 4.8 mm) nozzles. The nominal flow is suggested to be 1.8 m^3 per hour (0.50 l/sec).

Figure 44. Movable sprinklers are used to irrigate sugarcane in Finchaa Valley.

Agricultural Production

Sugarcane is the principal crop in Finchaa Sugar Estate (figure 45). Sesame and horticultural crops are also cultivated in small areas of the estate. Planting of seedlings and transplantation is done manually but cultivation and chemical spraying are accomplished using a semi-mechanized method.

The sugarcane productivity of the estate is one of the highest in the country at 160 t/ha. The fertilizers used in the estate include urea (1.5-4 qt/ha), diammonium phosphate (2.5 qt/ha). For

crop protection 2-4-D (3.5 l/ha), Atramite Combi (7 l/ha), Velpa 75 DF (0.8 kg/ha), Roundup (4.5 1/ha) and other insecticides are employed.

Figure 45. Sugarcane cultivation using sprinkler irrigation in Finchaa Valley.

Socioeconomic

Finchaa Sugar Estate has been established to produce quality and crystallized white sugar for the domestic markets. Finchaa Sugar Factory has a total capacity of producing 850,000 quintals of sugar in one production year (242 days). Unlike Wonji and Metahara sugar factories, Finchaa Sugar Factory does not export sugar to the international market as it is located far away from the market outlets in the country when compared to the other sugar producing factories. However, it sells sugar directly to the local market through the ESISC. The support center determines the floor price of sugar in the country through bidding. Traders who won the bid are obliged to fetch sugar from the three factories at the same price irrespective of the distance to the factories from the capital.

The factory is the sole producer of ethanol in the country. Its annual outputs are 8.1 million liters, of which more than 75 percent is exported to the international market. The factory produces two kinds of alcohol that can be utilized for power and drinking purposes. The demand for ethanol from local liquor factories is growing and it is currently beyond the capacity of the factory. As a result the factory has a plan to expand the total capacity to 12 million liters in the future.

The estate provides access to telecommunication, radio, and television facilities to its employees. The employees also have free access to use electricity for household consumption.

Environmental Impact

The Finchaa Valley was covered with indigenous trees before the establishment of the estate, but when the scheme was implemented the area was deforested and converted to sugarcane plantation. The increase in the number of settlers in the valley due to the establishment of the sugar estate also resulted in higher rates of illegal lumbering and charcoal production for fuel. This is creating pressure on the environment surrounding the irrigation scheme. In an effort to conserve the environment the Finchaa Irrigation Estate, through its environmental protection department, is distributing both indigenous and exotic tree species to the neighboring localities (Wallner 2006; Amdihun 2006).

INDRIS IRRIGATION SCHEME

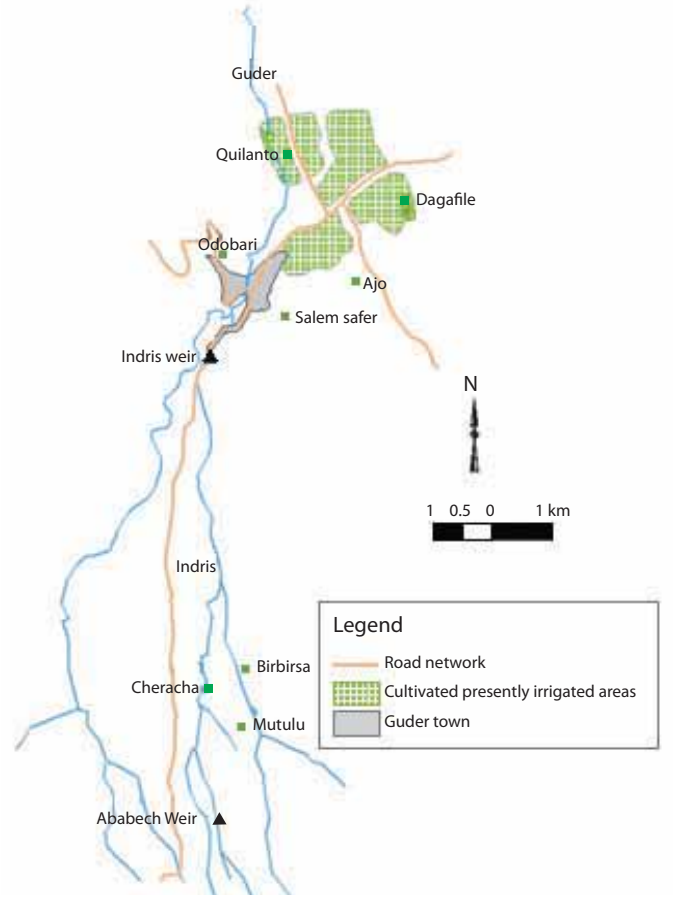
Table 10. Profile of Indris Irrigation Scheme.

Location	8°56'58"
	37°45'03"
Year of establishment	1980
Scheme type	Community-managed
Water source	Indris River
Diversion type	Concrete weirs
Irrigated area (ha)	570.75
Main crops	Onion, potato, pepper and tomato
Number of beneficiaries (households)	1,367

Location

Indris Irrigation Scheme is located 137 km west of Addis Ababa on the main road to Nekemt near Guder Town in the upper reaches of the Blue Nile River Basin as shown in figure 46 (OIDA 2006).

Figure 46. Indris Irrigation System.



Historical Background

Indris Irrigation Scheme was first established by the Ministry of Agriculture, Soil and Water Conservation Department in 1980. In 1992-1994 EEC/PADEP VI funded a project on the Indris Scheme to rehabilitate the diversion weir and canal system. The project also strengthened the water users associations in the scheme and helped in establishing an irrigation schedule for water distribution. Later in 1994 the German Agro-action together with Abebech Gobena Orphanage financed another small-scale irrigation project and constructed a weir on the Indris River upstream of the previous weir (Taffa Tulu 2002).

Physical Features

The irrigation scheme is found in the Blue Nile Basin and is characterized by mean annual rainfall of 1,059 mm and mean daily temperature of 17.4^{o}C. The irrigated area is undulating with slopes varying from 2-10 percent. The total irrigated area using the two diversion structures is 570.75 hectares. The Indris diversion, which is found downstream of Abebech Weir, is located at an elevation of 2,029 m a.m.s.l.

Clay soil is the main soil type in this irrigation scheme. The amount of clay ranges from 59 to 71 percent. The soil is suitable for agricultural production with Cation Exchange Capacity (CEC) of 14-27 milli-equivalent/100 grams (g) soil, Organic Matter (OM) of 0.9-1.8 percent, with a nearly neutral pH value of 6.35-7.68.

Employment Contribution

Irrigation water from the upstream Ababech diversion serves 347 households in three WUAs namely, Mutulu, Cheracha and Birbirsa. On the other hand, Indris diversion serves 1,020 households in five downstream WUAs namely, Odobari, Salem Safer, Ajo, Dagafile and Quilanto.

Irrigation Water Source and Management

The Indris River is the source of irrigation water to the irrigation scheme. Indris and Ababech weirs, which are located 2 km and 10 km, respectively, south of Guder Town on the Indris River, divert and supply irrigation water to eight WUAs downstream of these weirs in the irrigation schemes.

Ababech Weir is made of stone masonry and constructed upstream of the Indris Weir across the Indris River (figure 47). It has an outlet at its base to maintain some amount of flow for the downstream Indris Weir. A rectangular lined open canal with a screen structure at its inlet is used to abstract irrigation water from Ababech Weir (figure 48). This canal, which feeds a series of earthen canals, takes irrigation water through the irrigators' farmlands and villages and serves five WUAs. A manually operated gate made of iron sheet is used to control and regulate irrigation water at the headworks.

Irrigation water is applied using the furrow irrigation system. Furrow and plot dimensions vary in the different farms due to different farm shapes and the size of landholdings. However, irrigation plots with a width of 5.30 m X 32 m are commonly found. Furrow lengths vary from 4–5 m, and furrow spacing for vegetables is usually 80-85 cm with a furrow width of 50 cm. Field canals that are used to supply furrows usually have a width of 1-1.2 m.

Indris Weir, which is made of concrete, is found about 8 km south of Ababech Weir near Guder Town on the Indris River (figure 49). Two main canals from the left and right sides of the weir divert water to supply irrigation water to five WUAs and the Ambo College of Agriculture. An outlet on the left side of the weir discharges water to maintain the flow of the river. Further downstream this discharge is diverted and used by Hormat Engineering for industrial purposes.

At the Indris diversion a manually operated gate is used to control irrigation water and in the Ababech diversion irrigation water is not controlled at the diversion site but at the outlet from the main to secondary canal. Conveyance of irrigation water is mainly by open, unlined canals. Only about 1-2 percent of the canal network is lined. In the scheme, irrigation canal capacity declined due to sediment deposition, erosion and vegetation growth in the canals. Furrow irrigation is widely used to irrigate crops in the scheme but in some parts flood irrigation is still in practice. However, training was given to farmers on the benefits of using furrow irrigation so that they would abandon wild flooding.

Figure 47. Abebech Weir on the Indris River.

Figure 48. Rectangular main canal is used to convey irrigation water from the diversion.

Figure 49. Indris Weir supplies irrigation water to five WUAs.

Agricultural Production

Both rainfed and irrigated farming are practiced in the area. The main wet season crops are tef, wheat and maize while onion, potato, pepper and tomato are cultivated during the dry season using irrigation (figure 50). The diversion structures are also used to provide supplementary irrigation for rainfed crops.

Crop yields in the Guder area are 1.2 t/ha for tomato, 4 t/ha for potato, 0.8 t/ha for tef, 1.5 t/ha for wheat, and 2 t/ha for maize. Manure, urea and DAP are widely used by farmers to replenish the fertility of the soil and to boost agricultural productivity.

Figure 50. Crop production in Indris Irrigation Schemes.

Socioeconomic

The Indris irrigation scheme is a community-managed irrigation system where the irrigators organized themselves into water user associations and operate with the assistance of the district irrigation office. Based on the location of the weirs in the Indris watershed, it is possible to put WUAs into two categories: upstream and downstream groups. The upstream WUAs are Mutulu, Cheracha, and Birbirsa while Odobari, Salem Safer, Ajo, Dagafile and Quilanto constitute the downstream WUAs. Both groups rely on the income from agriculture to sustain rural livelihoods. However, an increasing number of households in both groups rely on non-farm income. But, whereas upstream groups rely on trading in agricultural products like fuelwood and hop leaves for an income, downstream groups rely more on daily labor in Guder Town (Kurian 2005).

There is little or no coordination between upstream water users at Ababech Dam (three WUAs) and downstream water users at Indris Dam (five WUAs). The only aspect that can be considered as coordination is that the Cheracha WUA receives water first on Thursday and Friday, followed by the Birbirsa WUA on Saturday and Sunday.

Sharecropping and land leasing arrangements are common in Indris. On average, downstream groups tend to have a small area irrigated from the weir as compared to upstream groups. Upstream groups also tend to be ethnically more homogeneous as compared to downstream groups.

Environmental Impact

There is no noticeable environmental impact in the system. However, it is apparent that during the dry weather all the river water is possibly diverted for irrigation without any consideration for environmental flows.

SILE IRRIGATION SCHEME

Table 11. Profile of Sile Irrigation Scheme.

Location	5°49' to 5°55' N
	37°26' to 37°29' E
Year of establishment	Early 1960s
Scheme type	State and private farms
Water source	Mainly from Sile River. Some private farms from Sego River
Diversion type	No structure on the river, a simple intake on the bank of Sile River
Total area (ha)	
Designed	1,490
Currently irrigated	500
Main crops	Cotton, maize and banana
Number of employees	256

Location

Sile Irrigation Scheme is located 27 km northwest of Arba Minch Town at an altitude of 1,120 m.a.s.l. in the Southern Nations, Nationalities and People's Regional State. The farm is along the Arba Minch-Gidole all weather gravel road and lies between Sile and Sego rivers as shown in figure 51.

Historical Background

Sile State Farm was established when the Government of Ethiopia nationalized private farms of the country in 1975. Three private farms that were operating in the Sile area since the early 1960s were nationalized to form the then Sile State Farm. After its establishment the concession area of the farm was expanded four to five times and the design and layout of the fields were changed by Ethiopian and Korean experts to suit the new area under the previous state farms. As a result of another restructuring, Sile farm is currently under Semen Omo State Farm Enterprise, which comprises Arba Minch, Abaya and Omo state farms in addition to Sile State Farm. The objectives of the establishment were to produce industrial and food crops for local consumption.

Figure 51. Sile Irrigation Scheme.

Physical Features

Sile State Farm and the surrounding area have a semi-arid climate with an average annual minimum and maximum temperature of 17^{O}C and 32^{O}C, respectively. The rainfall pattern is bimodal with an average annual rainfall of 729.6 mm. Most of the area of the farm is covered with very deep soil with silt loam and clay loam textures (Engdawork et al. 2002).

The total area of the state farm designed to be irrigated, with water from the Sile and Sego rivers, was about 1,500 hectares with an additional 400 hectares to be irrigated using springwater. Currently, the farm is taxed on 1,300 hectares. Due to various reasons the command area reduced over time. One of the main reasons for the decline is water shortage, which is due to the interest developed amongst the surrounding farmers to irrigate their own farms upstream of the scheme.

Employment Contribution

Sile Farm has a total of 256 permanent employees for carrying out its fieldwork as well as office activities. It also absorbs a large number of casual workers during planting, weeding and harvesting.

Irrigation Water Source and Management

Irrigation water is diverted from the Sile River using a simple intake from the bank of the river (figure 52). Because of the topography of the area, the Sile River flows in different directions at the intake point during different seasons and the state farm is forced to train the river annually so that it will divert the required amount of water into the farm.

The main canal, secondary and tertiary canals are all earthen with trapezoidal cross sections. Other structures such as division boxes, and road crossings are made of stone masonry. Manually operated gates made of iron sheets are in use in the farm even though most of them are not functional at present (figure 53).

Surface irrigation methods are employed to irrigate crops in the farm. Furrow irrigation is widely used to irrigate cotton, maize and banana. Cotton is first irrigated after 3-4 days of planting and then it is irrigated every three weeks for about five to seven times until it reaches maturity. On the other hand, banana is irrigated every week. However, there is a practice of planting banana on marshy parts of the farm to decrease the frequency of irrigation and reduce the water requirement of the farm during the peak dry season. Irrigation water is commonly applied by physically examining the conditions of the crops.

As the farm is using surface irrigation, a significant portion of the labor force of the farm is employed during irrigation. During first irrigation, a team consisting of eight people is employed and in the second irrigation the number reduces to five persons and it reduces further to reach four persons during the fifth irrigation.

Canal maintenance is usually performed by the state farm but sometimes the surrounding farmers also contribute labor as they use irrigation water from the state farm canal network.

Due to a lack of water storage structures there is a shortage of irrigation water in the irrigation scheme. As the surrounding farmers also practice irrigation there is competition for water. However, an agreement has been reached between the farmers and Sile Irrigation Scheme. According to this agreement the state farm is allowed to use water for 10 hours a day, and the remaining 14 hours are allocated to smallholder farmers.

Agricultural Production

The main crops cultivated in the farm are cotton, maize and banana. More than 80 percent of the farm is covered with cotton but, recently, there is a gradual shift towards banana (figure 54). Maize is the second highest in area of cultivation and the state farm sells it to employees at a reasonable price in order to attract casual laborers.

Land preparation and agronomic practices in the farm include; tilling the land to a depth of 25-30 cm, leaving the soil as it is for about 45 to 60 days, followed by disking and planting using a planter with ridge spacing of 90 cm for cotton, 80 cm for maize with a common row spacing of 20 cm (figure 55). The plant population targeted by the farm during planting is about 55,000/ha for cotton and 60,000/ha for maize.

Intensive crop cultivation is carried out by private farmers adjacent to the state farm. The main crops cultivated are banana, mango and avocado. The area upstream of the state farm, especially towards the intake from Sile River, is intensively cultivated with banana, to the extent that it is difficult to identify the homestead from the rest of the farm as both of them are covered by banana plantations.

Figure 52. Irrigation water is diverted to the scheme using a simple canal constructed through the bank of the Sile River.

Figure 53. Some of the water control structures at Sile.

Figure 54. Banana is gradually replacing cotton in the Sile Irrigation Scheme.

Figure 55. Mechanization is practiced for farm operation at Sile Irrigation Scheme.

Socioeconomic

Sile is a government-managed farm. The intake and system of channels at the various tiers are owned and controlled by the enterprise. The enterprise owns tools, machinery, land, buildings and trees. The main farming system is cash crops.

Marketing is carried out through the government marketing board through Semen Omo State Farms Enterprise. However, marketing of banana is also carried out by private dealers. The main marketing challenge of the state farm is the decline in market price of cotton. As a consequence, it is replacing cotton by other crops like banana. Access to both input and output markets is very good.

The management/institutional services include water distribution, system maintenance, assessment and collection of taxes, assistance and extension to farmers on water management at local level, input supplies, credit, marketing, finance, personnel, planning and monitoring. There is no other organization in the area capable of providing some of these services. There is no full hierarchy in the distribution of responsibilities. The main institutional constraints of the system are limited technical capacity, poor communication between farmers and the government agencies, inadequate coordination among agencies serving irrigated agriculture, poor state of the physical control structures, inadequate maintenance of the irrigation system, and lack of financial resources to maintain the proper functioning of the irrigation facilities.

Environmental Impact

There has been some deforestation caused by the establishment of the scheme due to continuous use of wood for fuel consumption. However, the shift in cropping pattern from cotton to perennial crops like banana in the state farm and surrounding banana cultivation by smallholder farmers makes the area evergreen and significantly reduces soil erosion that may create siltation problems in the nearby Lake Chamo. On the other hand, streamflow during dry seasons can fall to zero and environmental flows between the farm and the lake are ignored.

GOLGOTA IRRIGATION SCHEME

Table 12. Profile of Golgota Irrigation Scheme.

Location	8°38'52" N 39°45'17" E
Year of establishment	1976
Scheme type	Community-owned
Water source	Awash River
Diversion type	Temporary sill structure made of gabion
Total command area (ha)	850
Main crops	Onion, tomato, maize, sugarcane, banana, papaya, cabbage
Number of beneficiaries	554 households

Location

Golgota Irrigation Scheme is found in Upper Awash Valley along the Merti Jeju-Nura Era main road just before Nura Era Farm in Merti Woreda, Arsi Zone of Oromia Regional State.

Historical Background

The scheme was established when the Government of Ethiopia nationalized private farms in the area in 1976 and gave it to new settler farmers under the Ministry of Water Resources. Later the scheme was handed over to the Ethiopian Red Cross Society. During the change of government in 1991, the Red Cross left the scheme and the farmers in the area divided and shared the scheme by themselves. As a result it is now a community-managed scheme with support from the Oromia Irrigation Development Authority.

Physical Features

The Golgota community-managed irrigation scheme is situated between Merti Jeju and Nura Era farms, and as a result its physical characteristics very much resemble that of Upper Awash Agro-Industry Enterprise. The topography is gently sloping in the upper portion of the farm and is relatively level in the lower portion. The texture of the soil is mainly sandy loam but there is also the clay loam texture in the area. The total irrigated area in the scheme is 850 ha.

Employment Contribution

The total number of registered households that benefit from the irrigation scheme is 442. However, there are about 112 farming households that benefit from the irrigation scheme without registration.

Irrigation Water Source and Management

The source of irrigation water for Golgota Irrigation Scheme is the Awash River. A still structure made of gabion is used to raise the level of Awash River and divert irrigation water into Golgota Farm by gravity (figure 56). An earthen main canal with a width of about 3 m delivers water to the silting basin (figure 57). The silting basin, which is rectangular in shape with a width of about 5 meters, is used to settle and flush out the sediment through three manually operated metal gates built at the side of the basin into Awash River. After leaving the basin the water is delivered into two canals which are used to take the irrigation water to different parts of the irrigated field (Golgota, Genet and Argoba).

There are some discharge measurement facilities near the intake structure but they are not currently in use due to limited knowledge of irrigation water measurement by the irrigators (figure 58).

Furrow irrigation is the main method of irrigation used in the farm. Tomato, onion and maize are commonly irrigated using furrow irrigation (figure 59). Recently the farmers in the scheme started using basin irrigation to irrigate tef.

Irrigation water is distributed at a constant amount with a constant frequency rotation (full supply oriented rotation). The frequency of irrigation scheduling is carried out weekly at main canal level.

Maintenance of irrigation canals is conducted by human labor. The main canal is maintained three times a week for two hours. During a particular maintenance, about 200 people from the total households are engaged in carrying out this work.

Figure 56. A temporary structure is used to divert water from Awash River at Golgota.

Figure 57. A silting basin is employed to reduce the sediment load of water from the Awash River for irrigation.

Figure 58. Some of the gates have measuring gauges even though they are not used at present.

Agricultural Production

The main farming system is mixed cash and subsistence farming. The crops grown include onion, tomato, maize, sugarcane, banana, papaya and cabbage (figure 60). Planting time is variable. Tomato is usually planted after May. The cropping intensity is three times a year. Until now no crop rotation is in use. Onions are produced three times consecutively without adding any other crop in between.

Fertilizers used in the scheme are DAP and Urea at a rate of 200 kg/ha for both. The most important pests and diseases in this irrigation scheme are leaf miner, trips, ball worm, cut worm, whitefly, purple blotch and mosaic virus. Farmers utilize chemicals like Karate, Selecrone, Raedomile, and Tayudine to protect their crops from pests and diseases.

Figure 59. Furrow irrigation is used to irrigate crops like onion in the scheme.

Socioeconomic

Canal maintenance is carried out by the community. Those households that are not willing to participate in canal maintenance are fined 10 Birr per day by the WUA based on the bylaws established. The WUA assigns the canal clearing task on an individual basis. One household is usually given about 2.5 m length of the main canal and 5 m of the secondary canal. There is also a tractor committee that rents tractors for tillage operation and transport purposes.

Institutions that are providing services to the scheme include the UAAIE and Ethio-Itali Rural Development Project. The UAAIE provides technical support to Golgota Irrigation Scheme. Such support is given in the form of tractor maintenance services and welding services during maintenance of metal gates, which are provided free of charge. The Ethio-Itali Project supported the irrigation scheme by implementing a canal upgrade project to improve the conveyance efficiency of the scheme.

Figure 60. Crop mix (onion and maize) in Golgota Irrigation Scheme.

There is a social conflict in the irrigation scheme especially in the areas called “fifty two hectare” and Argoba. The conflict is between the locals and the people resettled in the area in the 1970s, which has created problems in carrying out normal irrigation practices.

Farm outputs are usually sold to merchants from Nazareth, Addis Ababa and Harar areas while it is still on the farm. The local dealers usually determine the price of farm products. Farmers usually complain about the way prices are determined as they are given low prices as compared to prices the products are sold for in the nearby local markets. However, due to the absence of a marketing cooperative established by the producers themselves, they are forced to sell their products without price negotiations.

The input supply, especially fertilizer from the government agencies, is good during the rainy season but there is no input supply during the dry season when irrigation is practiced intensively. As a result farmers in the area are obliged to buy from private input suppliers at high prices.

The scheme is connected by an all weather road to Nazareth. Some of the other facilities available in the scheme include electricity and telephone services.

Environmental Impact

Intensive irrigated agriculture with a cropping intensity of three crops per year without crop rotation is employed in this irrigation scheme. As a consequence, there are indications that the fertility status of the soil is declining from time to time and there is also a risk of soil salinity problems even though it has not been confirmed by laboratory analysis yet.

BILATE IRRIGATION SCHEME

Table 13. Profile of Bilate Irrigation Scheme.

Location	6°4'8.55" to 6°50'21" N 38°4'57" to 38°5'50" E
Year of establishment	1974
Scheme type	Government
Water source	Bilate River
Diversion type	Barrage with bays
Total area (ha)	1,264
Main crops	Tobacco, maize

Location

Bilate Irrigation Scheme is located in the Lower Bilate River Basin, a main tributary of Abaya Lake, southwest of Addis Ababa in Welayita Administrative Zone, Southern Nations, Nationalities and People's Regional State.

Historical Background

The farm was established in 1974.

Physical Features

The irrigation scheme is found in Lower Bilate River Basin. Bilate River Basin is one of the major river basins in the Ethiopian Rift Valley which drains into Lake Abaya. The watershed of the river extends approximately 5,500 km^2 and it greatly varies in relief. The altitude of the basin ranges from 1,285 m to 3,600 m a.m.s.l. The main soil type is loamy sand with a depth of 2-3 meters.

The climate of the basin is humid in the upstream sub-basin and it becomes semi-arid in the lower sub-basin as the elevation decreases. The average mean maximum and minimum temperatures are 32.6^{O}C and 13.3^{O}C, respectively. The rainfall is bimodal with an average annual rainfall of 733.95 mm. The surrounding area is covered with small bushes and open woodland. The total irrigated area of the scheme is 1,264 ha.

Irrigation Water Source and Management

The diversion structure of the Bilate Irrigation Scheme is a barrage with nine bays (figure 61). The intake has a settling basin with a trapezoidal section. The main canal is a trapezoidal channel with lined and unlined parts (figure 62).

Other structures include vertical drops with rectangular crest, rectangular steel gates and pipe culverts. One main canal, pipelines and another six secondary canals supply the field with irrigation water. Pipe culverts are employed to convey irrigation water across roads and depression in the irrigation scheme. Tertiary canals of the farm are poorly maintained and as a consequence they lost their shape and have irregular shapes at the moment (Aredo 2006).

Figure 61. A barrage with nine bays is used to divert irrigation water for Bilate Irrigation Scheme.

Agricultural Production

The major part of the valley, except for the foot slope and the stony areas, are used for tobacco and maize production. Crop rotation is practiced between tobacco and maize.

Socioeconomic

Bilate Tobacco Farm is a government-owned farm which was under the administrative control and management of the ETMC based in Addis Ababa in the past and since recently it is under the National Tobacco Enterprise. The National Tobacco Enterprise gives planning and operating guidelines as well as providing various supporting services such as supply of inputs and marketing of cured tobacco, etc.

The socioeconomic situation of the population surrounding the project site is variable and ranges from nomadic life to a settled agricultural production system. Some of the peasants in the vicinity are encouraged to produce tobacco and sell the product to the farm. The communities in the locality and those coming from other locations are working as daily laborers for the farm. Diverse ethnic, language and religious groups inhabit the area.

Figure 62. Main canal of Bilate Irrigation Scheme.

Infrastructure in the farm include all weather gravel roads to Awassa and Sodo towns. However, there is no daily public transport link from these towns to Bilate except during market days, which is usually once a week. Other infrastructure, such as a junior school, electricity and domestic water supply are available for the communities in the irrigation scheme.

MEKI-ZIWAY IRRIGATION SCHEME

Table 14. Profile of Meki-Ziway Irrigation Scheme.

Location	8°10' N
	30°35' E
Year of establishment	1967
Scheme type	Government
Water source	Ziway Lake
Diversion type	Pump station
Irrigated area (ha)	763
Crops	
Major	Maize, beans
Minor	Tomato, grape vine, banana, papaya and avocado
Number of employees	2,000

Location

Meki-Ziway Irrigation Scheme is located in the Central Rift Valley of Ethiopia in Dugda Bora Woreda, Oromia Regional State, about 135 km south of Addis Ababa near the main road to Awassa.

History

The scheme was constructed in 1967. It was initially established as a smallholder dairy, but after nationalization its purpose changed to producing crops and horticultural products. The original design was done by the State Farm Technical Department and it was constructed by the technical section of the farm in cooperation with the Ethiopian Fruit and Horticultural Corporation.

Physical Features

The area is found in the Rift Valley Lakes Basin near Ziway Lake with an altitude ranging from 1,630–1,650 m.a.s.l. The general topography slopes towards the east and south. It is characterized by a semi-arid climate with an average annual rainfall of about 700 mm. The mean maximum temperature is 28^{O}C in February. The rate of evapotranspiration is 3.4 mm/day with a peak value of 4.6 mm/day. The main soil type in the irrigated field is sandy loam. Currently, the total irrigated area is about 763 hectares, which, by far, exceeds the designed area of 300 ha.

Employment Contribution

The total number of employees in the scheme is 2,000; about half of them are females. Activities like grading, harvesting and picking are mostly jobs that are carried out by women.

Irrigation Water Source and Management

Lake Ziway is the water source of the Ziway Irrigation Scheme. Water is pumped and diverted to the scheme using centrifugal pumps. The water delivery infrastructure includes, open channel, pipelines, lined canals, and unlined canals. The type of water control equipment used is of a fixed proportional division, and a manually operated gate. The location of water control and discharge measurement equipment is at primary, secondary and tertiary levels. The type of discharge measurement facilities in use are calibrated sections. The type of irrigation scheduling used is of a constant amount, and varied frequency (modified frequency rotation), where irrigation water is applied every 5 days for shallow-rooted crops and every 10 days for deep-rooted crops. The predominant on-farm irrigation practice is surface (furrow) irrigation but abandoned sprinkler and drip irrigation systems also exist. Tree crops like papaya, avocado, grape vine and banana are cultivated using the basin irrigation method. The availability of water is sufficient, but the possible reason for inadequate water supply at tailend of the canals is due to sediment deposition and vegetation growth in canals.

Agricultural Production

In the scheme the major crops cultivated are maize and beans, while other crops like tomato, grape vine, banana, papaya and avocado are also common in the enterprise.

Socioeconomic

The type of management is government agency. The operation of the scheme can be rated as good. The management/institutional services include: water distribution, system maintenance, input supplies, marketing, finance, personnel, planning and monitoring, etc. The scheme's access to both input and output markets is very good. Pricing is determined by local and international markets (through pre-agreed contracts). The records kept include; water use, cropping pattern, input costs, yields and meteorological data. The enterprise pays tax for land, which used to be 15 birr/ha but it has been increased to 135 birr/ha since 2003. The main institutional constraint of the system is the lack of financial resources to maintain the proper functioning of the irrigation facilities. The management team for the farm, consisting of the irrigation and land development head, water foreman and technicians at division boxes, meet once a week.

In the last couple of years some of the command areas of Ziway farm were transferred to commercial horticulture and flower farmers. These new developments are providing ample employment opportunities, water saving aspects and higher productivity of land.

Environmental Impact

The major environmental concern in the area is the decline in the water level of Lake Ziway, which supplies irrigation water to the enterprise and other irrigated farms. There is also salinity and alkalinity problems in the irrigated area of the enterprise especially near the lake. However, there are no waterlogging, acidity and erosion problems seen in the enterprise. Even though deforestation has been caused due to the cutting down of trees for firewood and charcoal use in the area, there is also a positive change in the microclimate due to the irrigation scheme in the area. Since the recent expansion of commercial irrigated farming, there are growing concerns on possible environmental impacts of some of the practices on the Ziway Lake and on groundwater quality.

CONCLUSION

In this report, we have discussed the characteristics of most of the case study sites of the project "Impact of Irrigation on Poverty and Environment in Ethiopia" that are intentionally located in different parts and basins of the country. The report is designed based on rapid assessment to characterize all the sites that are used as detailed investigation sites of the project. The type of these case study sites includes simple farmer managed schemes and complex agro-industry enterprises. The size of the studied schemes ranges from 1,200 to 14,600 ha for medium and large size schemes and from 850 to 2,224 for small-scale farmer managed irrigation schemes.

Most of the studied irrigation schemes use water from perennial rivers through diversions using a weir or by direct pumping. The common discharge controlling structures are manually operated iron gates with graduated staffs to measure water level which is converted later into discharge using standard tables. In most of the cases trapezoidal earthen canals are used to convey water to the irrigation fields. Surface irrigation techniques, particularly furrow irrigation, is the most commonly used irrigation method with the exception of Finchaa Sugar Estate where large-scale sugarcane cultivation has been practiced using sprinkler irrigation. Recently, there is a gradual change in some of the case study sites from field ditches and siphons to a more labor and water saving technology called hydroflume for field irrigation water application.

The main crops cultivated in government managed large-scale irrigation schemes include sugarcane, cotton, tobacco, and fruits such as oranges, mandarin, tomato, guava, grape vine while crops such as onion, potato, pepper, tomato, banana, are commonly cropped in community managed small-scale irrigation schemes. Recently, in some of the medium and large-scale irrigation schemes there is a significant shift in cropping patterns as a result of low market prices and crop damage due to pests. For example, the Middle Awash Agricultural Development Enterprise is now shifting from banana plantation to cotton production as opposed to the Sile Irrigation Scheme where cotton is being replaced by banana.

Government managed irrigation schemes usually export their products such as sugar, linted cotton, and green beans to the international market. However, there are also cases where some of these schemes are confined to the local market due to their relative location and distance to international markets (Finchaa Sugar Estate). Community managed schemes usually sell most of their products to local markets and use the remaining for household consumption. The most marketable crops in community managed schemes are onion, tomato, cabbage, and pulses like chickpea and lentil.

A large number of people have been beneficiaries of these irrigation schemes. For example, the four large-scale irrigation schemes: Wonji Sugar Estate; Metahara Sugar Estate; Upper Awash Agro-Industry Enterprise; and Finchaa Sugar Estate, alone, support more than 100,000 employees and their families. Recognizing this fact, the Government of Ethiopia is currently expanding irrigation areas mainly near these four irrigation schemes under the framework of the National Water Sector Development Program.

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