# Efficient Water Use for Agricultural Production (EWUAP) Project

# RAPID BASELINE ASSESSMENT OF AGRICULTURAL WATER IN ETHIOPIA

**By**

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# PREFACE

The EWUAP project of the NBI – SVP has initiated measures to bring together the regional and national stakeholders in the riparian countries to develop a shared vision on common issues related to increasing the availability of water and its efficient use for agricultural production. As a preparatory to the planned major undertakings, EWUAP project has initiated the Rapid Baseline Assessment (RBA) of the agricultural sector in member countries.

The objective of this RBA, which took place from 21 August – 11 September 2006 was to compile secondary information related to efficient use of water for agricultural production. The assignment focused on complementing the information assembled in the country reports by gathering additional information including identification of opportunities and needs related to the exchange of best practices for water harvesting, community-managed irrigation, and public and private-managed irrigation. The assessment also presents national stakeholders related to the subject.

The methodology used in preparing this report involves literature review and interviews with informants at relevant institutions. Published and unpublished documents were collected from various sources including the Ministry of Water Resources, Ministry of Agriculture and Rural Development, WFP, GTZ, and others. The exposure of the author to various parts of Ethiopia in matters related to water harvesting, watershed management and small scale irrigation is also reflected. The compilation of the information in this paper is not limited to areas or practices within the Nile basin but also to all parts of the country.

Based on the document review and primary information collected from interviews with key informants, the major needs of the sector and possible areas of intervention are identified and presented in this paper. Potential sites that could be considered for a study tour at national or regional levels are presented towards the end of the report (i.e. section 11).

The terms of reference for this assignment required that the RBA report should not exceed 35 pages and font sizes of 10 – 11. To comply with this requirement, Tables and photographs were removed from the main report and presented in the Annexes.

This final report has included comments given from the EWUAP Project Manager and from participants of a workshop convened to evaluate the report. The half day workshop was held in Addis Ababa on 03

October 2006, with participants from MOWR, MOARD, EARO, and OIDA and in the presence of Technical Advisory Committee (TAC) member.

## ACKNOWLEDGEMENTS

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## LIST OF ACRONYM AND ABBREVIATIONS

| | |
|---|---|
| **ADLI** | Agricultural Development Led Industrialization |
| **AEZ** | Agro ecological Zone |
| **AMAREW** | Amhara Micro-enterprise Development, Agricultural Research, Extension and Watershed Management |
| **ANRS** | Amhara National Regional State |
| **ARARI** | Amhara Regional Agricultural Research Institute |
| **AU** | Alemaya University |
| **CIDA** | Canadian International Development Agency |
| **CGIAR** | Consultative Group on International Agricultural Research |
| **CMI** | Community Managed Irrigation |
| **CSA** | Central Statistical Agency |
| **COSAER** | Commission for Sustainable Agriculture and Environmental Rehabilitation |
| **COSAERT** | Commission for Sustainable Agriculture and Environmental Rehabilitation in Tigray |
| **CPC** | Cooperative Promotion Commission |
| **DA** | Development Agent |
| **DHP** | Dry Land Husbandry Project |
| **EARO** | Ethiopian Agricultural Research Organization |
| **ENTRO** | Eastern Nile Technical Regional Office |
| **EPA** | Environmental Protection Authority |
| **ESRDF** | Ethiopian Social Rehabilitation Fund |
| **ESTC** | Ethiopian Science and Technology Commission |
| **EU** | European Union |
| **EWUAP** | Efficient Water Use for Agricultural Production |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FDRE** | Federal Democratic Republic of Ethiopia |
| **GIS** | Geographic Information System |
| **GoE** | Government of Ethiopia |
| **GTZ** | German Development Cooperation |
| **IFAD** | International Fund for Agricultural Development |
| **ILRI** | International Livestock Research Institute |
| **IPM** | Integrated Pest Management |

| | |
|---|---|
| **IWMI** | International Water Management Institute |
| **MERET** | Managing Environment Resources to Enable Transition to more Sustainable Livelihoods |
| **MOA** | Ministry of Agriculture |
| **MoARD** | Ministry of Agriculture and Rural Development |
| **MOFED** | Ministry of Finance and Economic Development |
| **MoWR** | Ministry of Water Resources |
| **MU** | Mekelle University |
| **NBI** | Nile Basin Initiative |
| **ND** | No Date |
| **O&M** | Operation and Maintenance |
| **OCHA** | Office for the Coordination of Humanitarian Affairs |
| **OIDA** | Oromia Irrigation Development Authority |
| **OSSREA** | Organization for Social Science Research in Eastern and Southern Africa |
| **PD** | Person Days |
| **PMI** | Public Managed Irrigation |
| **qt** | Quintal |
| **RBA** | Rapid Baseline Assessment |
| **REST** | Relief Society of Tigray |
| **SDPRP** | Sustainable Development and Poverty Reduction Program |
| **SIDA** | Swedish international Development Agency |
| **SLM** | Sustainable Land Management |
| **SNNPR** | Southern Nations, Nationalities and Peoples Region |
| **SPFS** | Special Program for Food Security in Ethiopia |
| **SSI** | Small Scale Irrigation |
| **SVP** | Shared Vision Program |
| **SWC** | Soil and Water Conservation |
| **TBWRD** | Tigray Bureau of Water Resource Development |
| **TOR** | Terms of Reference |
| **TVET** | Technical, Vocational, Educational and Training |
| **UN** | United Nations |
| **USAID** | United States Agency for International Development |
| **WSDP** | Water Sector Development Program |
| **WB** | World Bank |
| **WBISPP** | Woody Biomass Inventory and Strategic Planning Project |
| **WFP** | World Food Programme |
| **WH** | Water Harvesting |
| **WUA** | Water Users Association |

# EXECUTIVE SUMMARY

The Ethiopian economy is dominated by subsistence small holder agriculture and is considered as the source of growth for the Ethiopian Economy. As yet, the Ethiopian agriculture, both in crop and livestock production, is rainfall dependent. It is characterized by low-input and low-output system.

On top of the shortage or irregularities of the rainfall pattern, there are many inherent and intentional wastage of water in both irrigation and rain fed agricultural systems. Irrigation efficiencies are in the range of <30 – 50%. The low efficiency is mainly due to conveyance losses. The reviewed reports mentioned nothing about losses due to deep percolation and tail water runoff.

Water use efficiency of rain fed agriculture is also low due to many factors that reduce the effectiveness of rainfall (reduction in infiltrated amount or increase in runoff volume). The factors responsible for increasing the runoff rate in Ethiopia include: rough terrain coupled with the absence of vegetative cover; unsustainable land management practices; land degradation and the like.

The importance and role of water in transforming Ethiopian agriculture is clearly stated in the Rural Development and Water Policies and Strategies of the country. However, lack of the requisite capacity in both research and extension systems and absence of rules and regulations to improve water productivity are among the major constraints. Cognizant of this, the government has put capacity building strategy as the core task as of 2002.

Water harvesting, which includes in-situ moisture conservation and small water storages, is and will continue to be the priority intervention in the water stressed areas of Ethiopia. This intervention has high potential for enhancing the productivity of the rain fed agriculture, recharging of the groundwater, and to some extent growing vegetables in small plots.

The community managed irrigation schemes are constrained by the lack of adequate support from the extension and research system. They are also constrained by lack/weakness of community based institutions that enable collective action on common issues such as proper utilization of water and maintenance of structures.

The public managed irrigation schemes are noted to involve poor irrigation efficiencies and salinity build-up in the agricultural fields. No document is available on the performance of private managed irrigation schemes.

For effective and sustainable use of the available water resources, the stakeholders have recognized the importance of adequately addressing the management of the land (watershed) from which the water is harvested. Thus, the planning, development and management of WH and CMI interventions need to be integrated with other land management issues within the watershed. To this effect, appropriate capacity building programs are required to the farmers and technical personnel from the extension and research institutions.

The Water and Rural Development Policies and Strategies of the country reflect the interest in improving water and land productivity. There are some research and extension initiatives. As yet, there are some research results and pockets of practical experiences related to improving water productivity. However, lack of proper mechanism of replication and/or scaling up of these best practices is noted as constraint. This would call for the concerted and coordinated effort of all stake holders in the planning and implementation of measures related to improving agricultural productivity. Such effort has to start with rectifying the problems of integration and coordination within and between the extension and research systems.

# 1. BACKGROUND INFORMATION

## 1.1 Main Agricultural Production Systems

Mixed crop livestock agricultural production system is practiced by 80% of the country's population inhabiting the Ethiopian highland, which is the land above 1500m altitude and covering 45% of the total land mass. The dominant crops grown are mainly cereals, pulses and oil crops, enset, coffee and horticultural crops. Declining landholding sizes because of population growth and deteriorating soil fertility are among the biggest challenges facing the agricultural production system in the highland (FAO, 2005).

Mixed crop livestock production system is also practiced in some lowlands (with elevation less than 1500m). The crops grown are drought-tolerant varieties of maize, sorghum, wheat, teff, oil crops and pulses (FAO, 2005).

Pastoral system is a source of livelihood for about 10 percent of the total population and is practiced in the Afar and Somali regions and the Borena zone. Livestock is the major livelihood basis of these populations that are highly mobile in search of water and grazing. Some lowland varieties of maize, sorghum and other cereals are also cultivated on flood plains or as rain fed crops (FAO, 2005).

## 1.2 Role of Agriculture in the Economy of Ethiopia

The Ethiopian economy is dominated by subsistence small holder agriculture. About 84% of the over 75 million[1] population of Ethiopia draws their livelihoods predominantly from rain fed agriculture. Contribution of agriculture to GDP was 57% and 42% in 1991 and 2003, respectively (Andrews et al, 2005).

Agriculture is considered as the source of growth for the Ethiopian Economy. The Ethiopian SDPRP targets an economic growth of 7% per year in order to halve poverty by 2015 (MOFED, 2002; Andrews et al, 2005). The strategy focuses at transforming agriculture from mostly subsistence to commercial production. The growth in agriculture would act as a catalyst for the development of industry and exports, and the generation of off-farm employment and income. Specifically, the government aims to increase agricultural value-added growth from an annual 2.2 percent historically to 7.5 percent a year, and non-

[1] CSA population figure for July 2006

agriculture growth from 5.8 percent to 6.6 percent. In the agricultural sector, this strong improvement in real output is premised on productivity growth rising from an annual 0.4 percent historically during 1991–2003 to an average of 9 percent a year over the medium term (MOFED, 2002; Andrews et al, 2005).

## 1.3 Agricultural Productivity

The Ethiopian agriculture, both in crop and livestock production, is rainfall dependent. It is characterized by low-input and low-output system (Seme et al., 2004). The CSA crop sample survey data for 2002 – 2005 (Annex 1-Table 1.1) shows the low level of crop productivity in Ethiopia.

Stemming from the interest to transform the agricultural productivity of the country, the government has been focusing on the dissemination of yield enhancing technologies such as improved seeds, fertilizer, irrigation and the like. In the livestock sector, the main improved technologies considered include improved breeds, animal feeds, and animal health care and honey production technologies. The crop-related technologies disseminated to the farmers have shown a significant increase in crop yields (Annex 1-Table 1.2). Similarly, milk yield from improved crossbred dairy cattle was noted to be over 4000 liters over a longer lactation period as compared to 300 – 400 liters from an indigenous breed over a lactation period of eight months (Seme et al, 2004).

However, the current level of adoption of technologies is very low. According to CSA estimates for 2003/2004 crop-season, out of the 9,654,159 ha cultivated by peasants in Ethiopia only 1.25% was irrigated. The level of adoption of the other improved technologies in the same crop-season was also low as shown below (CSA, 2005):
Percent of cultivated area covered with improved seed = 3.67%
Percent of cultivated area where fertilizer was applied = 40.22%
Percent of cultivated area where pesticides were applied = 9.18%
Cognizant of this, efforts are being made to scale up the dissemination of existing and new improved technologies to the farmers including rain water harvesting and small scale irrigation.

# 2. CONSTRAINTS TO THE AGRICULTURE SECTOR

## 2.1 Climatic Constraints

### (a) Rainfall Variability Affecting Rain fed Agriculture

Agricultural production (crop, livestock feed and watering, and woody biomass) are strongly correlated to rainfall in Ethiopia. A reduction and/or irregularity in the seasonal rainfall often results in adverse affect on the livelihoods of millions of the rural population since many decades back. This is reinforced by an IWMI study that poverty in the semi arid areas is mainly caused by inadequate availability of water for crop, livestock and other enterprises. It is also stated that the shortage of water is not caused by low rainfall but also by capacity limitations and the poor distribution of rainwater - leading to short periods of too much water and flooding and long periods of too little water (Hatibu, 2003). Moisture stress, caused by prolonged dry spells between rains, in rain fed agriculture of arid and semi arid regions is responsible for a decrease in yield by about 70% or sometimes a total crop failure (McHugh et al, 2004 adopted from Rockstrom[2] et al, 2002).

Variations in rainfall and weather conditions are among the factors responsible for the instability of the agricultural growth in Ethiopia. Annual agricultural growth declined from 2.2% in the 1960s to 0.7% in the 1970s and 0.1% in the 1980s. Since 1991, a combination of the positive effects of policy initiatives and good rains allowed the country to achieve food self-sufficiency and export food in 1996/97. However, bad weather – a combination of rainfall deficits during the growing season and excess rainfall during the ripening and harvest season – has reversed that situation in 1997/98, demonstrating the dependence of agriculture on climatic factors (BCEOM – MoWR, 1998).

Though there was a positive growth trend in agricultural production during 1991 – 1997 (Annex 2- Table 2.1) productivity was low with an average yield of 1.2 ton/ha for food grains, 0.6 ton/ha for pulses and 0.5 ton/ha for oil seeds in the Abbay basin[3] (BCEOM – MoWR, 1998). In the Tekeze basin, during the 1994 cropping season, average yield of wheat, barley and maize were: 1.4 ton/ha, 1.2 ton/ha, and 1.5 ton/ha, respectively. Yield of tomato, onion and carrot were in the range of 6.0 – 6.5 ton/ha (NEDECO – DHV, 1998). This was confirmed by an IMF analysis (Andrews et al, 2005) that during 1991–2003, agricultural

[2] Rockstrom, J et al 2002. Rainwater Management for Increased Productivity among Small-Holder Farmers in Drought Prone Environments. Physics and Chemistry of the Earth. PP 949 – 959.

[3] The Abbay basin is endowed with better agricultural land and climatic conditions compared to other part of Ethiopia; and yet productivity is so low.

growth was driven mostly by increases in the area under cultivation, rather than improvements in productivity. While the area under cultivation increased at an average rate of 5.7 percent a year, crop yields rose on average by only 0.4 percent a year. However, the GDP growth in Ethiopia, where agriculture is the dominant contributor, has a declined trend as shown in Annex 2-Figure 2.1, with the lowest values corresponding to drought years.

#### (b) Rainfall Variability Affecting Irrigated Agriculture

Irregularities of rainfall do not only affect the rain fed cultivation but also cause reduction of irrigated land due to shortage of irrigation water in reservoirs and streams/springs. This is a common phenomenon in many parts of Ethiopia. One incidence of a decline in stream flow rate, following a low rainfall season, was noted in 2004 by an IFAD evaluation mission quoting the concern of the irrigators in the headwaters of Tekeze basin (IFAD, 2005). The effect of low rainfall is highly pronounced in reservoirs with the decline in the size of irrigable area. A typical example of such case is shown for Mai Negus reservoir in Tigray, (Annex 2-Table 2.2). The Mai Negus reservoir dam was designed (considering 75% dependable rainfall) to store 2.38 million $m^3$ and to irrigate 123.9ha of land. But, due to low inflow, the irrigated area varied between 59.4% and 88.2% of the command area during five consecutive years (Mintesinot et al., 2004).

#### (c) Livestock Productivity Constrained by Water Supply

Livestock production is an integral part of the agricultural system of the highland and the major source of livelihood in the lowland pastoral areas. Water availability for livestock is critical in the lowlands as well as in many parts of the highland, where rainfall is inadequate in amount and distribution. Most of the year, animals have to walk long distances in search of water and are usually watered once in two to three days (McCornick P.G. et al. (eds), 2003).

### 2.2 Constraints related to Physiographic and Geologic Conditions

#### (a) Low productivity of Rainwater in Vertisol Areas

Vertisol cover about 12.61 million ha in Ethiopia out of which 7.6 million ha or 63% is found in the highlands (Tekalign et al, 1993 adapted from Berhanu Debele[4], 1985). Despite the availability of such big area and the positive attributes of Vertisol, like relatively high moisture storage capacity[5] and several favorable chemical properties, only about 30% of the Vertisol area in the Ethiopian highlands is used to grow low-yielding annual food crops and the remaining is under natural pasture for dry-season grazing (Tekalign et al, 1993). The primary production constraint in the Vertisol areas is water logging during the growing season caused by high rainfall and by the high content of swelling clays in these soils. The Vertisol are characterized by the accumulation of excess water in the soil profile and on the soil surface causing serious problems for growth of most of the crop plants. In post rainy season, shallow rooted crops suffer from moisture deficiency. As a result, the current productivity levels of Vertisol areas are very low (Tekalign et al, 1993).

### (b) Leaky Geologic Formation along Canal Routes and Reservoir Bottom

A review on the small scale geologic map of Ethiopia reveals that water tightness of reservoirs/ponds and a canal route is a serious constraint in maximizing productivity per unit of water. Indeed, many ponds and micro-dams constructed during the last few years suffered heavy leakage. Corrective measures are often too expensive. Attempts were being done to line ponds using imported PVC sheet in many parts of Ethiopia.

### (c) Steep Slope and Rugged Terrain

The Ethiopian landscape is dominated by undulating slopes and hilly – mountainous terrain. Such landscape tends to increase the volume and velocity of runoff, which in turn increases the erosion rate. The vegetative cover is the primary buffer zones for rain water allowing it infiltrate in to the soil. However, due to human interference and other natural factors most of the landscape is devoid of its vegetative cover. Consequently, much of the rainwater is wasted as runoff.

## 2.3 Land Degradation Induced Moisture/Water Deficiency

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[4] Berhanu Debele. 1985. The Vertisols of Ethiopia: their properties, classification and management. Fifth Meeting of the Eastern African Sub-Committee for Soil Correlation and Land Evaluation. Wad Medani, Sudan, 5-10 December 1983. World Soil Resources Reports No. 56. FAO (Food and Agriculture Organization), Rome. pp. 31-54.

[5] Soil measurement at five sites in the Ethiopian highlands, in 1986/1987, showed that during the general vegetative, reproductive and maturation stages of crops in the areas, the Vertisol stored 16, 19 and 37% more moisture, respectively, than the Alfisols.

On top of the shortage or irregularities of the rainfall pattern, Ethiopia also faces many problems that reduce the effectiveness of rainfall (reduction in infiltrated amount or increase in runoff volume). The first factor responsible for increasing the runoff rate is the rough terrain coupled with the absence of vegetative cover and wrong land management practices. Second factor responsible for inducing moisture deficiency to plants is land degradation (due to surface sealing, reduction of soil depth[6] and consequently reduction of water holding capacity). Surface sealing promotes runoff and reduces rainfall infiltration and soil moisture. Compaction is also a problem in some areas, causing difficulties for plowing, reducing rainfall infiltration, restricting root growth and consequently affecting agricultural production adversely.

Some reports indicate that on average 2 – 3% of agriculture GDP[7] is lost annually because of land degradation, the major cause being erosion by runoff. This problem contributes again to the continued rural poverty and increased household vulnerability, and the overall negative impact on economic performance.

Erosion in the catchments of reservoir dams is a serious problem in Ethiopia. There are many reservoirs that are heavily filled up with sediment as a result of which the irrigable area is reduced. Annex 2 (Annex 2-Table 2.5) shows reservoir dams where dead storage level was filled with sediment deposition earlier than anticipated. The designers of the reservoirs obtained the design sedimentation rate from literature, which was based on a sediment sampling conducted on streams around Mekelle in 1974 - 1976 (personal communication with the designers). The limitation in using such data directly was that, firstly the data had to be updated in view of the changes in land use. Secondly, the data could not be taken, as representative to all areas of interest for there is substantial temporal and spatial variability in factors causing sedimentation.

An underestimated sedimentation rate gives wrong conclusion with regard to the feasibility of the reservoir. Probably, it might also mislead planners and authorities on the urgency required to treat the catchment area.

## 2.4 Management Induced Wastage of Rainwater

[6] Research in Ethiopia has shown that erosion is severe on cultivated land, which therefore is the primary source of river sediment and with Transboundary implications.
[7] Source: Zeleke G. and Yesuf M. 2006. (Unpublished) Proposal for a cost benefit Framework to support pro-SLM Decision Making in Ethiopia.

### (a) Shallow Tillage Depth

Most Ethiopian farmers use the traditional ox drawn plow to prepare seed bed. In many cases, the depth of plow is in the range of 12 – 15 cm (Feldner et al., 2004). In dry or compacted soils the depth of plow is often less than 10 cm resulting in limited room for water storage and root growth. As a result, crops exhibit symptoms of moisture stress within a short period following the end of a rain event. The widespread existence of a plow-pan in cultivated fields has been concluded as one of the major limiting factor to increased crop production in the Ethiopian Highlands (Feldner et al., 2004).

### (b) Construction of Steep Ditches and Furrows to Dispose Excess Runoff

Studies indicate that more than 70% of the direct rain falling on a crop-field is lost as non-productive evaporation or flows in to sinks before it is used by plants; only 4 – 9% of the rainwater is used for crop transpiration (Hatibu, 2003).

On top of the above mentioned inherent wastage of rainwater, there is also wastage of rainwater induced by erroneous cultural practices. Due to high intensity of rainfall (and/or presence of hardpan, low permeability of soils etc.) a temporary water logging problem is common in many places of Ethiopia (Feldner, 2004), even in fields with slopes greater than 3%. With the intention of disposing excess runoff, farmers construct many ditches at an interval of 10 – 30 m along a steep gradient (>5%). The ditches are made to end up at an earthen waterway constructed perpendicular to the major slope (Annex 2-Photo 2.1). The ditches are constructed immediately after the seeding is completed, or when the soil is very loose. In some cases the farmers align their furrows in the steeper direction. As a result, (1) severe erosion occurs inside the ditch and the waterway and (2) the proportion of rainfall transformed to runoff is increased – lowering further the productivity of rain. Neither the farmers nor the extension service are attempting to generate/implement practices that can retain the temporarily excess rain water for use during periods of dry spell. (Exception to this is the small dugouts constructed in low rainfall areas). Researchers could have also strived to find crop varieties and practices that could withstand the temporary water logging problems and the sporadic dry spells.

### (c) Use of Dung and Crop Residue for Fuel

It is apparent that organic matter improves soil fertility and the water holding capacity of soils. But, the lack of fuel wood has forced farmers to use crop residues and dung for fuel. The negative implication of using dung and crop residue for fuel is quantified in terms of loss of nutrient as shown in Annex 2-Table 2.3**.** Such decline in soil fertility would further reduce the productivity of rain water.

### (d) Removal of Vegetative Cover from Slopes

In Ethiopia, which is a country dominated by steep and rugged terrain, the vegetative cover and the litter are the primary buffer zones for rain water allowing it infiltrate in to the soil. It is apparent that any slight action that would interfere with the stability of the vegetative cover of steep slopes would have a magnified consequence compared to areas with mild and gentle slope. Many studies indicate that deforestation and overgrazing are persisting problems and major causes of land degradation in Ethiopia. These problems are occurring in response to increasing population, absence of measures to intensify production on existing cultivated land. Deforestation rate in connection with the expansion of agriculture in Ethiopia is estimated to be in the range of 80,000 to 200,000 ha per annum (EPA, 1997). Besides, farmers let their livestock to graze freely along steep slope areas and farm lands during the non growing period. Free movement of livestock aggravates reduction of vegetative cover, compaction of the soil (thereby increasing runoff coefficient), and destroying SWC works.

In general, the prevailing deforestation and overgrazing are contributing to increasing the proportion of rainwater transformed to runoff – reducing the productive use of rain water. Research conducted on a 6% slope land under different soil cover condition in 1986 – 1987 at Holleta (at the headwaters of Awash River Basin) confirms this fact (Annex 2-Table 2.4).

### (e) Cultivation on Steep Slopes

Cultivation on hilly and steep slope areas is the prevailing practice in many parts of Ethiopia. Such practice aggravates the transformation of rain water to runoff. The consequent effect is manifested in terms of reduction in stream flow and decline in yield and depth of ground water.

## 2.5 Capacity Limitations

### (a) Capacity Limitations in Agronomic Extension and Water Management

According to an IWMI study, the limitation in the availability of water in semi arid areas (like Ethiopia) is not caused by low rainfall but lack of capacity for sustainable management and use of the available water (Hatibu, 2003). Capacity limitation at every stage of the project cycle is already recognized by the Ethiopian government as a major constraint in the implementation of development programs. For instance, extension supports in water management and irrigation agronomy are weak due to limitations in technical capacity.

Field observations and interviews with extension workers and farmers reveal that there is a significant gap between the recommended and currently applied agronomic and water management practices. For instance, tomato crops are planted at a row spacing of 30 – 40 cm instead of the recommended 1.2 – 1.5m. Consequently, the tomato leaves comes in contact with the irrigation water in the furrows leading to damage by blight disease; and yet no preventive fungicides are applied (personal observation). The problem is related to the lack of appropriate training and resources to enable staff to implement effectively what they have learned (Landell Mills, 2004). In general, there is a need for a technical support in the area of irrigation agronomy and water management.

The limitations in the extension services, specifically in the area of irrigated agriculture and SWC works at the catchments has also been noticed by IFAD as a potential threat to undermine the desired impact of irrigation schemes (IFAD, 2005). Thus, more work is still required to maximize benefit per unit volume of water.

Failure to give full support for the establishment or strengthening of WUAs is another drawback of the extension system.

### (b) Faulty Planning, Design and Construction

The prevailing problems in CMI schemes are not associated only with poor extension but are also caused by cumulative effects of poor planning and implementation. Shortcomings attributed to capacity limitations at planning stage are very common (IWMI et al, 2004) as can be seen from the following example:

There are many cases of reduction in planned irrigable area due to shortage of water during periods of low flows, which is associated with drought. Alternative measures were not planned for the periods of low flows;

Shortage of water caused by reservoir sedimentation is also common. This could have been averted if the catchment area were addressed as an integral part of the irrigation scheme.

Shortage of water caused due to excessive diversion of water by farmers situated towards the head of the supply canal (either to grow sugar cane or to over irrigate their plot) is very common. This could have been addressed by preparing and enforcing appropriate operation guidelines.
In some schemes farmers anticipate for maintenance tasks either from the government or the financing agency. This could have been handled by involving the community at the early stage of the project cycle;

In some schemes pump capacities are not commensurate with the planned irrigable area. Besides, a spare pump is not kept in case the one pump fails.

There are many water harvesting and irrigation schemes that are abandoned and/or operating below their expected level (Awulachew, 2005). The main factors responsible for this are faulty designs, poor construction techniques and lack of skill in proper operation and maintenance.

An assessment conducted in 1999 on one hundred irrigation schemes in Oromia region showed that 17% of the schemes had failed, 42% performed at less than 50% of their capacity and 51%[8] performed at greater than 50% of their capacity (Annen, 2001). A major problem identified, was insufficient collaboration between the relevant government institutions, which have a stake in irrigation. It was noted that the agricultural extension workers were insufficiently qualified and equipped for the complex extension tasks of irrigation agronomy, soil fertility management, crop protection, etc. Water users associations were insufficiently trained to manage schemes in a technically, economically and socially sustainable way. Input supply was insufficient (Annen, 2001).

### (c) Lack of Adequate Research and Extension Support

Research and extension support in irrigation water management, irrigation agronomy and marketing is poor or with inadequate coverage. The research institutes have been constrained by lack of capacity and

[8] The author of the indicated information did not realize that the percentages do not add up to 100%.

experience on SWC and use of water in agriculture (Gete et al 2006). There are only few research stations that deal with irrigation agronomy research situated in limited agro ecological zones. The existing good experiences on which new best practices can be built are found in scattered areas.[9] An exception to this is that, the AMAREW project in Amhara region has been engaged in promoting linkage and integration of research and extension in on-farm activities in selected pilot areas as of 2002 (Brhane et al., 2005).

The importance of implementing integrated watershed-management practices in the upland areas, as a means of retarding sedimentation to reservoirs and maintaining stream flow rate is well recognized by all stakeholders. But, SWC works are implemented in the catchment areas of only some irrigation schemes (IFAD, 2005). Often, the proposed and implemented SWC measures are more of physical structures. To some extent biological measures and closure of a portion of the catchment from human and livestock interference are also implemented. In some instances, the SWC efforts had yielded some benefit in rehabilitating the physical environment. This can be explained in terms of re-growth of indigenous shrubs and grass, reappearance of springs after being dry for long time, stabilization of gullies and the like. Good examples of such achievement are the WFP – MERET project and the GTZ/IFSP South Gonder projects. The later has been involved, among others, in the judicious selection of productive and multipurpose plant species, which includes fruit trees, plant species for gully rehabilitation and rangeland improvement, etc. (Feldner, 2004).

In most parts of the country, however, the technologies introduced as part of the SWC measure were not observed in bringing a significant economic benefit to the upstream community whose livelihood is connected directly with the catchment areas of the irrigation schemes.

For instance, the expected yield from biological SWC measures, as outlined in the Awash River basin master plan (HALCROW – EVDSA, 1989), is as follows:

(a) Fuel wood

- from hill side closure : 10 $m^3$/ha after 20 years;
- from conservation forestry : 75 $m^3$/ha after 20 years;
- from community woodlot : 100 $m^3$/ha after 8 years.

[9] One example: Ground water recharge works integrated with abstraction of water from shallow wells for irrigation in Tigray.

(b) Fodder production

- from conservation forestry and woodlot 0.2 ton/ha fro initial 2 years;
- from hillside closure 0.5 ton/ha for entire period

The problem with the expected benefit from the existing biological SWC measures, as outlined above, is that 1) the farmers have to wait for a long period before the first harvest and 2) the yield is too low. Under such conditions, the upland farmers would not be interested to invest their time and labor for a benefit expected over the long term. Therefore, it is high time to accelerate the identification and dissemination of plant materials (and associated technologies – e.g. apiculture) such that the community inhabiting the catchment would get quick visible benefit.

## 2.6 Market Constraints

Water use efficiency in irrigation farms situated close to big urban markets is higher compared to those in remote areas. The former earn better income from the sale of their diversified crops. Such better income helps them to invest more in acquiring pumps and pipes and undertaking timely maintenance works (IWMI et al., 2004). On the other hand, farmers in remote areas grow more of maize which is not a high value crop. According to a survey made by COSAERT in six irrigation schemes in 1999 and nine schemes in 2001, the proportion of area covered with maize was 49.1% and 89.5%, respectively (unpublished data). IWMI financed research work also noted the proportion of maize crop, in 2003/04, was 43.26%, 51.36% and 50.39% in Meila, Haiba, and Mai Negus CMI schemes, respectively (Mintesinot et al., 2005). The farmers' reason for growing more of maize was that firstly it can be consumed directly and the stalk can be used as source of feed and fuel. Secondly, it is less laborious and not perishable. Thirdly, the seed and pesticides required for growing horticulture are expensive and not available easily (IWMI et al., 2004).

In 2001, the price of maize was extremely low throughout the country at ETB 40.0 per quintal in Arba Minch, ETB 70.00 in Awassa, ETB 80.00 in Addis Ababa and ETB 90.00 in Mekelle. In some areas, price of maize as low as ETB 20/qt was reported (Annen, 2001). From the maize dominated cropping pattern point of view, the irrigation schemes are not yet managed to a situation where benefit is the highest per unit volume of water. Under such conditions, it would be difficult for the irrigators to cover the O&M costs let alone to take a share of the investment cost.

The impediments in linking irrigated farms in remote areas to markets which can absorb their production are related to one or a combination of the following: difficulties in physical access; the domination of the market by traders who dictate price to farmers who have no bargaining power, and the smallness of the local market (IFAD, 2005).

Moreover, cropping is not staggered to ensure continuous supply of produce and stabilized prices. Often, there is surplus supply congested within a short time at harvest, becoming a cause for depressing prices of vegetables. The implication of depressed vegetable prices is that the income of the farmers is too low to repay credit taken for farm inputs let alone to cover the compulsory operation and maintenance cost of the irrigation scheme. For example, Meki-Ziway irrigation scheme (in Oromia region) failed largely because farmers could not carryout maintenance and could not afford the electricity fee to run the pumps (Awulachew et al., 2005).

## 2.7 Institutional and Policy related Constraints

### (a) Institutional Instability

The irrigation sector is characterized by frequent restructuring and reorganization (MOWR, 2001). Too frequently changing institutional arrangements in the irrigation sector have occurred during the last decade (IFAD, 2005). Due to frequent changes in organizational structures technical staffs are frequently transferred from one organization to another or from one department to the other within an organization. There was continuous staff turnover (IWMI et al., 2004). There has been also confusion relating to organizational responsibility for WH (Landell Mills, 2004). The problem associated with frequent reorganization of institutions is the loss of institutional learning and experience built up over many years (Metaferia Consulting Engineers et al 2002, Gete et al, 2006).

### (b) Lack of Integration and Coordination

On top of capacity limitations, the lack of integration within the research system (among disciplines and among institutions located in different places) and with the extension system is a persisting problem. The extension system is also constrained by lack of integration and coordination among disciplines within itself (Gete et al, 2006).

Important technologies such as conservation tillage, tie-ridging, the broad-bed maker (BBM), etc. are not properly exploited due to adoption problems or lack of proper technology dissemination mechanisms, which in turn is related to the weak linkages between research and extension (Gete et al 2006). Successful practices are limited to pilot project areas or research centers. Replication and scaling up of these efforts remains a challenge (Gete et al., 2006).

### (c) Weak Monitoring and Evaluation Systems

Temporal and spatial data that characterize WH and irrigation schemes are often lacking. Weak monitoring and evaluation systems have been recognized as a drawback in the implementation of irrigation schemes (IFAD, 2005; IWMI et al, 2004).

### (d) Institutional Gap in Operation and Maintenance Function

The absence of appropriate organs at the Wereda level is the major cause for the lack of guidance in irrigation operation and maintenance (MOWR, 2001). In many irrigation schemes, maintenance duties are not properly done. This is reflected by inefficient scheme performance resulting from poor canal maintenance, such as no removal of silt and weeds, no repair of breached sections. These problems in turn cause a reduction in canal capacity leading to reduced water supply for irrigation. A typical example of such problem is at Doni Kombe CMI situated in Awash basin – Oromia region, where the canal capacity was reduced such that it supplied water to only 80 ha out of the total irrigable area of 195 ha (IWMI et al 2004). On the other hand, there are some WUAs that successfully achieved effective water distribution mechanism different from original designs and conduct successful scheme maintenance activities (Awulachew et al., 2005).

The dominant water conveyance means in most of the irrigation scheme is unlined canal. With the exception of the PMI in the Awash River Basin, there is no means of measuring the amount of water diverted from the supply canal to the field canals and then to the irrigated field[10].

### (e) Limitations in Drafting and Implementing Regulations

[10] Same as the footnote indicated below.

Enabling legislations on such issues as empowering of WUA, cost recovery, operation, maintenance and administration of schemes, water use rights are absent (MOWR, 2001). Many cases that need the urgent formulation and enforcement of regulations are now arising. Few such cases are shown below:

- **Absence of Water Charges/fees:** The Ethiopian water resource management policy and strategy documents clearly noted for the establishment and implementation of tariff structure for water services. The tariff structure is to be based on site-specific characteristics of the schemes, and ensure that water prices lead projects to full cost recovery. Water charges related to domestic water supply are put in to effect throughout the country. The only irrigation water charge that has been in effect is at the Awash Valley irrigation farms, which is 3 Birr per 1000 $m^3$ of water. However, there is no detailed legal ground to support the implementation of the water charge. There were times when the clients failed to effect payment and the responsible agency lacked to handle the case in arbitration and/or litigation[11]. All this is attributed to the lack of appropriate regulations.[12] Some of the WUAs do have byelaws but in many cases are breached or not observed. On the other hand, indigenous irrigation schemes have unwritten but effective byelaws.

- **Water Right:** Conflicts between upstream and downstream water users are increasing in many parts of the country. New diversions or pumps are being installed upstream of existing diversion weirs resulting in shortage of water for the existing CMI schemes. Such cases are being taken to the court and other authorities, but it appears there would be no immediate solution (example: a case in Eastern Tigray in 2006) (personal communication with TBWRD). Digging of a shallow well very close (10 – 20 m) to an existing well is being noted as source of conflict. Consequently, there is a decline in the yield of the wells causing moisture stress in the irrigated crops. After noticing the effects of too closely spaced wells, farmers are now getting sensitive against new attempts to dig a well by their neighbor. Farmers are taking the case to the court and relevant authorities whenever a neighbor attempts to dig a well very close to an existing one. But, there are no rules and regulations to address the issues.

- **Regulations to Control Wastage of Irrigation Water:** There is excessive application of water by farmers situated towards the head of the supply canal resulting in shortage of water by the downstream users. Besides, there is wastage of water resulting from the perception that says

[11] Personal communication with Team leader (a)Team Leader, Water Utilization Control and Structure Safety Follow-up Team, MOWR; and (b) Team Leader, Irrigation Team, MOWR.

[12] Based on personal observation and also communication with (a) Head, WH and SSI Department, MOARD; (b) Team Leader, SSI Team MOARD; (c)Team Leader, Water Utilization Control and Structure Safety Follow-up Team, MOWR; and (d) Team Leader, Irrigation Team, MOWR.

"*water is a free good* ". In some sites, water is diverted to a field canal beyond the capacity of a farmer and results in damaging the land (by water logging or erosion). Often there are conflicts among the users. One possible solution to such problems would be the introduction of water fees, which is not being considered currently.

- **Enforcing Integrated Watershed Management Approach:** Over the last few years there were attempts to plan and implement integrated water harvesting, soil conservation and other agricultural activities on micro watershed (200 – 500 ha) basis. To this effect, the Ministry of Agriculture and Rural Development conducted staff trainings on many occasions and prepared many guidelines. However, the extension support is predominantly continuing in scattered and uncoordinated way.

- **Enforcing IPM:** MOARD advocates for the incorporation of integrated pest management (IPM) as an element of the crop production system. In practice, however, the crop production system appears to neglect the inclusion of the IPM. It is apparent that vegetable crops are highly vulnerable to pests and disease. Due to the lack of IPM programs, there is a drastic reduction in yield and the profitability of farming (Awulachew et al., 2005).

# 3. OPPORTUNITIES IN THE AGRICULTURE SECTOR

## 3.1 Availability of Resources

Ethiopia with a total area of about 1.13 million $km^2$ has an estimated arable land resource potential of 55 million ha. Out of this, only 16.6 million ha or 30% of the arable potential is cultivated (MOWR, 2001).

Master plan studies and related river basin surveys show that the aggregate annual runoff from the nine river basins of Ethiopia amounts to 122 billion $m^3$. The three largest river basins (Abbay, Baro-Akobo and Omo-Gibe) contribute 76% of the total runoff from a catchment area comprising only 32% of the total area of the country. The ground water resource is estimated as 2.6 billion $m^3$ (MOWR, 2002).

About 84% of the 75 million people is rural population engaged in agriculture and related activities (CSA, 2005).

## 3.2 Government Commitment to the Sector

### (a) Policy Support

The importance and role of water in transforming Ethiopian agriculture is clearly stated in the rural development and water policies of the country (see section 9 below).

### (b) Organizational Setup of Government Institutions

The MOARD organizational setup reflects the Government's interest to effectively utilize the available water resources. Four departments of the MOARD have mandates and functions associated with supporting farmers in availing and utilization of water for agriculture. These are:

i. Water harvesting and Small Scale Irrigation Department,
ii. Forestry, Soil Conservation and Land Use Planning Department,
iii. Crop Production Department (that includes irrigation agronomy team and other teams for rain fed crop production)
iv. Extension Department

The extension department is organized based on rainfall amount so as to address the different farming systems and to utilize the potentials of the different agro ecologies as follows:

i. Extension team for high rainfall areas,
ii. Extension team for low rainfall (moisture deficit) areas, and
iii. Extension team for pastoral areas.

The extension system, with technical staff at the federal, regional, Wereda and Kebele levels, offers significant opportunity for the dissemination of best practices. The current extension system is called Participatory Demonstration and Training Extension System (PADETES) and was developed in 1995 in response to ADLI. During 1995 – 2002, the extension approach enabled to increase crop yield 2 – 4 times (Annex 3-Table 3.1). For instance, Maize yield under farmers practice and PADETES was in the range of 1.1 – 1.8 and 3.7 – 5.8 tons/ha, respectively. The number of farmers involved in the PADETES package increased from 32,000 in 1995 to about 4.2 million in 2002 (Ebrahim, 2005).

On top of the above mentioned departments, the MOARD has established a project office for the coordination of MERET project, which is responsible for the implementation of WH, SWC and capacity building activities focusing on participatory watershed management planning.

The research institutes almost cover the major agro ecological zones of the country (Gete et al, 2006). The establishment of these research institutes and the coverage of their operational funding indicate the awareness and commitment of the government.

### (c) Capacity Building as Core Strategy of the Government

Capacity building is one of the pillars of the Government's Rural Development policy and strategy. In addition to the strengthening of existing universities, the government has established 25 agricultural TVET[13] and 6 water colleges in various parts of the country (Awulachew et al., 2005). The agricultural TVET colleges aim at training junior level agricultural practitioners who will be posted to Farmers Training Centers (FTC) as extension agents (DA) to train and provide technical assistance to farmers. There will be three DAs per Kebele or FTC – one each for livestock and crop and the third one for SWC, WH, and Irrigation.

[13] TVET = Technical, Vocational, Educational and Training

As part of the capacity building initiatives, many technical guidelines related to irrigation water management were prepared by various agencies including IFAD, ESRDF, FAO and others. Copies of such guidelines are available in the libraries of the regional and federal government offices. Some practitioners on the design and construction aspect are using the ESRDF guideline (IWMI, 2004). The ESRDF-financed guidelines include, but not limited to, the following:

- Guidelines on SSI project watershed management,
- Guidelines on SSI project headwork and irrigation system design,
- Guidelines on construction of SSI project,
- Manual on operation and maintenance of SSI project,
- Guidelines on SSI project on institutionalizing WUA.

But, the guidelines related to operation and maintenance and irrigation agronomy are not used as DAs complain about the lack of adequate training and reference material.

### (d) Conservation Based Agricultural Development Strategy

Soil and water conservation received significant attention by the Ethiopian government following the 1973 – 74 drought (Gete et al., 2006). Since then, with support from donors, various SWC measures were implemented in many parts of the country in both scattered way and on watershed basis. Cognizant of the government directions and efforts, the master plan studies of Abbay and Tekeze basins also recommended the adoption of conservation based agronomic practices among others (BCEOM – MoWR, 1998).

### (e) Community Based Participatory Watershed Development Approach

The adoption of the watershed approach commenced in the 1980's, where large watersheds (30 – 40 thousand hectares) were considered as planning unit for the purpose of protecting the environment through SWC works. However, efforts made on such large watershed sizes had unsatisfactory results due to lack of effective community participation, and difficulty in planning and implementing project activities (Lakew et al, 2005). Stemming from the lessons learned from experience, MoARD, WFP and other agencies have considered a catchment of 200 – 500 ha as optimal *watershed* size in ensuring effective implementation and sustainability[14]. Often, the indicated 200 – 500 ha planning unit is referenced as "*micro watershed"*.

There are many initiatives to conserve and improve the productivity of land and water resources on small watershed-based approaches. The specific objectives of the watershed-based approaches as outlined in a recently published guideline (Lakew et al, 2005) are:

i. Conserving soil, rainwater and vegetation effectively for productive uses,
ii. Harvesting surplus water to create water sources in addition to groundwater recharge,
iii. Promoting sustainable farming and stabilize crop yields by adopting suitable soil, water, nutrient and crop management practices,
iv. Rehabilitating and reclaiming marginal lands through appropriate conservation measures and mix of trees, shrubs and grasses based on land potential, and
v. Enhancing the income of individuals by the diversified agriculture produce, increased employment opportunities.

The importance of catchment planning and development in irrigation schemes is also appreciated by implementing agencies in view of water resource evaluation, of the assessment of soil and water conservation requirements and of the prevention and resolution of conflicts between user groups (IFAD, 2005). In line with this, some agencies in the country are conducting their irrigation feasibility process in the context of the entire catchment. However, the efforts are limited to certain areas and still many agencies and practitioners treat each irrigation scheme as an isolated entity. Donors such as WFP, GTZ, SIDA and others are supporting pilot integrated watershed development projects.

In light of the current trend, the WH component of EWUAP should capitalize on this approach – i.e. considering the *micro watershed* as the planning unit.

### (f) Credit and Finance for Implementing SSI and WH Structures

There are many independent credit and saving institutions in the country established to provide services to the rural community. Since 2003, there have been initiatives to link the credit with WH and associated

[14] MoARD. 2005. Community Based Participatory Watershed Development: A Guideline.

technologies. The construction of a pond was among the criteria that makes a household eligible for a loan[15] (Landell Mills, 2004).

The government through the decentralized system allots a budget for the implementation of WH/SSI works. On top of this, many agencies such as WFP, GTZ, SIDA, IFAD, CIDA and NGOs (such as REST in Tigray and ORDA in Amhara) have been involved in financing capacity building and/or implementation of WH/SSI activities (King G. and Leul K., 2005).

## *3.3 Technologies and Best Practices*

### (a) Plants for Watershed Rehabilitation

The implementation of both physical and biological measures is instrumental for increasing rainfall infiltration. The end result of the SWC measures is greater soil moisture availability for crops and natural vegetation, as well as enhanced ground-water replenishment. Cognizant of this, during 2001 – 2004, the project known by "*GTZ/ IFSP South Gonder*" (in Amhara Region) tested eighty indigenous and exotic multi purpose trees and shrubs, legumes and grasses. In addition to their adaptability, the plant species had to serve multipurpose functions in terms of soil and water conservation, biomass production (fodder, firewood, and building material), soil enrichment, etc. and be suited to various land-use types within watersheds. Focus was also made to the species that can offer immediate benefits. Accordingly, fifty plant species successfully passed the screening process (Feldner, et al 2004).

### (b) Increasing Tillage Depth in Clay Soil to Increase Moisture Availability

It is apparent that deeper plowing in clay soil would create conducive condition for growth of crop roots and enhance the infiltration rate of water. Cognizant of this fact, Ethiopian farmers plow their fields repeatedly up to 2 – 7 times. However, the traditional oxen drawn plow plows the soil to a limited depth of 10 – 15 cm. Consequently, a plow pan is created at a depth of 10 – 15 cm (Feldner et al 2004). The plow pan restricts downward movement of water. In view of this, in 1999, the GTZ IFSP project in Debretabor, Amhara Region designed and tested an implement (named as *Tenkara Kend* (Annex 3-Photo 3.1) with a capability of penetrating the impermeable hard layer. The cutting blade is capable of penetrating the soil to a depth of 35cm at the same time that it creates a furrow which is both deeper (approximately 25cm) and wider than that created by the indigenous plow. Prior to large scale

[15] Loan repayment period of 4 years with 9% interest rate

manufacturing, field trials were made over three cropping seasons to compare the effect of the modified implement as compared with the traditional plow. Results showed that the modified implement enabled to get a yield increment of 15 – 40%; larger increment being associated with higher number of plowing (Annex 3-Table 3.2).

Another experiment has been conducted in 2003 in Lenche Dima watershed, in Amhara region, to investigate if increasing tillage depth could increase available soil water such that plants can survive the dry spells between rains. The soil was clay loam (and has bulk density of 1.56 $Mg/m^3$). Rainfall and evaporation during the growing season (July – December) were 516 mm and 981.6 mm, respectively. The result shows that increasing the depth of tillage could increase moisture availability for the plant resulting in significant biomass and crop yield increase as shown in Annex 3-Table 3.3 (McHugh et al, 2004). The research was conducted on small plots and thus there is a need for scaling up of the practice.[16] Besides, the research also indicates for the identification and promotion of affordable plowing technologies as a means of improving the productivity of water.

In Alicho Wuriro Wereda ( in SNNPR) some farmers prefer hoeing to ox plowing for two related reasons: (1) in some cases the land could be too compacted and difficult for the ox to pull the plow; and (2) crop yield is better from a field cultivated by hoeing than from a field plowed with an ox drawn plow. This could be attributed partly to the difference in breaking the compacted soil layer and resulting in better rooting depth and water holding capacity of the soil. The depth of till was observed to be 10 – 20 cm and 30 – 50 cm with the ox drawn plow and hoeing, respectively (Leul, 2006).

### (c) Improving Water Productivity in Well–Drained Soil

An experiment conducted from July – September 2003, in Melkassa research center (Awash Valley) on a well drained silt-clay loam soil (bulk density 1.13 $gm/cm^3$) showed conventional tillage (ox-drawn plow) with mulch gave higher sorghum grain yields as compared to zero tillage with and without mulching. The combined effect of the tillage and crop residue management is associated with greater water conservation and has resulted in increased grain yield. On the other hand, grain yield from the field with tied ridges and mulch was less possibly due to excessive soil moisture during the growing season and temporary water logging. Sorghum grain yield with tied ridging but no mulch was found to be at comparable level to highest yield levels obtained due to the thicker mulch under conventional tillage treatment (Annex 3-

[16] Research in dry areas of Tanzania has shown that sub-soiling coupled with manure can lead to fourfold increase in yields of maize per unit of land (Hatibu 2003).

Table 3.4). The positive effect of tied ridges on crop yield under semi arid condition was also reported in 1989 as shown in Annex 3-Table 3.5.

### (d) Broad Bed and Furrow (BBF) Technology for Vertisol

Research works have been initiated as of the 1980s in Ethiopia aiming at minimizing water accumulation on the soil surface and improving aeration within the top 30 – 40 cm of the profile. Among the management practices introduced, the Broad Bed and Furrow (BBF) technology was found to be the most effective and economically attractive ((Tekalign et al, 1993). The bed height of the BBF was found to be the significant parameter. Results from experiments at Ginchi and Akaki (Oromia) in 1991 have shown that BBF with 26 cm bed heights produced significantly higher grain yields than the commonly used 13 cm high BBF (Annex 3-Table 3.6). Same sources also noted that in 1988 open ditches (30 cm wide, 40cm deep and spaced 15 m) were effective in improving drainage and increasing barley yields. High runoff and erosion rate were the drawbacks associated with the use of BBF (Annex 3-Table 3.7). Water drained from individual plots can be wasted as runoff and may cause severe erosion unless the issue is addressed systematically at a watershed level.

MOARD conducted trials of improved vertisol management techniques during 1993 – 2004 and reported 50 – 80% increase in wheat yield (Annex 3-Table 3.8). In April 2006, MOARD issued a guideline on the management of vertisol to be used by DAs.

### (e) Potential of Using Residual Moisture in Vertisol

Soil moisture measurements during 1986/87 in five Vertisol sites in the Ethiopian highlands showed the presence of large amount of water during the harvest period[17]. The measurements indicate that the Vertisol remain moist or wet throughout the year at a depth of 50 and 100 cm. The influence of cracks (which can be up to 45 cm deep) on soil moisture depletion during the fallow period is negligible at the 50-100 cm depth. Thus, the residual soil moisture could support a second crop if the top 20 cm soil layer can be wetted to maximum recharge (98 mm) with supplemental irrigation (Jutzi et al (eds) 1988). The water drained from the Vertisol field during the rainy season could be stored and used as source of water for supplementary irrigation of a second crop.

### (f) Crop Breeding

[17] soil moisture at 50 cm and 100 cm in a vertisol site was 0.36-0.58 $cm^3\ cm^{-3}$

Crop breeding is recognized as one means of improving water productivity in agriculture (Jinendrasa, 2003). That is, crop varieties that yield more with the same amount of water, or shorter duration and varieties that consume less water, increase productivity of water.

A number of breeding activities have been conducted in Ethiopia to replace low yielding cultivars of the major crops[18] (Teff (*eragrostis teff*), maize, sorghum, etc.) and other crops with better performing varieties. The breeding efforts resulted in the development and release of cultivars that have high grain yield, high grain quality with wide or specific adaptation and early maturing (Seifu, 1997; EARO et al 2001). The national average grain yield of teff and Maize in 2004/05 crop season was 0.948 and 1.719 ton/ha, respectively (CSA, 2005). Improved varieties of teff give a grain yield of 1.70 – 2.00 ton/ha on farmers field and 2.20 – 2.80 ton/ha under research-managed large farms (Seifu, 1997). The yields of the improved maize varieties released during 1993 – 2000 ranges from 3 to 12 ton/ha, (Annex 3-Table 3.9). The table (Annex 3-Table 3.9) also indicates the significant yield difference under research and farmers condition. Understanding of the causes for such differences in yield would give a clue for designing and implementing interventions.

### (g) Development of Sorghum Varieties and Hybrids

Sorghum is the dominant lowland/dry land crop covering an area of 1,253,620 ha or 16.4% of the cereal covered land in 2004/05 crop season in Ethiopia (CSA, 2005). As of the 1960s research works were conducted to identify sorghum varieties and hybrids that can give better yield and escape drought. A total of 11 varieties have been released for production in the dry land areas (Geremew et al, 2004).

### (h) Transplanting for Rain fed Cropping

With the purpose of “extending” the effective growing season for sorghum crop, seedling transplanting started in 2000 as an observation trial and repeated in 2001 by MU. The specific objective of the trial includes, among others, “*to demonstrate whether transplanting as an agronomic practice can be a means of reducing risk associated with direct sowing in areas with delayed onset and early cessation of rainfall*”. The result shows that sorghum yields from transplanted plots was greater than that from direct

[18] Major Cereal Crops and their Area Coverage and Yield in 2004/05 Crop SeasonTeffMaizeSorghumWheatCerealCropped Area, ha2,135,553.01,392,916.01,253,620.01,398,215.07,637,524.0Percent of Cereal Covered Area, %28.018.216.418.3National Average Yield, ton/ha1.01.71.41.6(Data Source :CSA 2005)

sown plots. The yield for direct sown sorghum was very low because very few plants reached maturity due to lack of moisture as the rain season was very short (Mitiku et al., 2004).

### (i) Transplanting for Cropping with Supplementary Irrigation

Growing vegetables during the rainy season is difficult mainly due to crop disease and damage caused by hails and high intensity rains. However, in some places farmers grow vegetable crops during the rainy season and get better price compared to what they get during the dry season. The vegetables are planted at the beginning of the rains and in case of tomato and pepper, are transplanted after the heavy showers of July (Landell Mills, 2004).

### (j) Wetland Cropping

Wetlands cover 13,669 $km^2$ or 1.14% of the country's land mass (Abebe Y.D. et al, 2003). According to environmentalists, the Ethiopian wetlands are being lost or altered by unregulated over utilization that includes the construction of dams for the expansion of irrigation and human settlement. On the other hand, wetland cultivation has been used as a source of livelihood in south west Ethiopia since 1911. A wide range of indigenous knowledge in favor of sustainable wetland management is noted to exist in places such as Ilubabor – Oromia (Abebe Y.D. et al, 2003). The Ethiopian Wetland Research Program (EWRP) established in 1997 has generated enormous information on the wetlands of south western Ethiopia.

## 3.4 Indigenous Knowledge Related to Water Use

### (a) Indigenous Knowledge in Moisture Deficit Areas

There are some indigenous practices used to enhance water productivity and also as a coping strategy against moisture deficiency. Among the predominantly used practice is planting of drought tolerant and/or early maturing crops. The demerit of such crops is that they are low yielding crops. (The possibility of identifying early maturing and yet high yielding crops needs to be addressed by researchers).

Some farmers in the highlands rectify the moisture deficiency in their plot by diverting intermittent runoff flowing along creeks, road side ditches and cutoff drains. In some lowland areas, the farmers use spate irrigation by diverting runoff generated from the rainfall occurring in the highland. In connection with the spate irrigation, farmers construct level bunds at a spacing of 5 – 10 m for the purpose of attaining uniform water distribution (personal observation).

Those farmers with prior indigenous knowledge of runoff diversion or spate irrigation were observed to be better adopters of new SSI and WH technologies and utilize the harvested water effectively (Landell Mills, 2004; Awulachew et al., 2005).

### (b) Indigenous Knowledge in Vertisol Areas

Very effective surface drainage is practiced on the high elevation Inewari plateau at 2600 m altitude in central Ethiopia. Raised beds about 80 cm wide, with 40 cm-wide furrows in between, are established each year on about 35 000 ha. This work is done by hand, without the help of any tool, which results in considerable human drudgery and low economic returns to labor (Tekalign et al, 1993). In many highland Vertisol areas farmers follow a strategy of avoiding much of the water logging effect by planting crops late in the season. The crops thus rely on residual soil moisture. The drawback of such practice is the underutilization of the potential length of growing period and the resulting low crop yields (Tekalign et al, 1993).

## 3.5 Topographic Advantage of Using Piped Flow for Irrigation Water

Examination of 11 irrigation projects constructed in the headwaters of Tekeze basin in Tigray revealed that the average elevation difference between the reservoir outlet and the end of the supply canal is 1.15m per 100m. The slope of the field, perpendicular to the supply canal, is often more than 1%. In addition to the indicated elevation difference, the head above the outlet pipe, often up to 10m, could be sufficient to drive the flow of water through pipes (Leul, 1998). Besides, many irrigation schemes based on river diversions also involve many drop structures along supply canals and field canals.

Thus, there is high potential for piped flow with gravity being the source of energy to drive the flow. This implies that there is high potential for producing more crops per unit of water.

# 4. ROLE OF WATER IN THE AGRICULTURE SECTOR

It is apparent that agriculture is the major water consuming sector in the country. Rain fed agriculture is almost the source of all food crops in Ethiopia with the irrigation sub-sector accounting for only about 3 percent of the food crops. The areas equipped for irrigation in 2002 under CMI and PMI were about 186,300 ha and 97,700 ha, respectively (FAO, 2005).

Based on the total irrigated area, cropping pattern and calendar, annual agricultural water use is estimated to be in the order of 5.2 $km^3$, while domestic and industrial water withdrawals are estimated to be about 0.33 and 0.02 $km^3$ respectively (FAO, 2005). The WSDP of Ethiopia has indicated that, the country cannot meet the large food deficits through rain fed production alone. Even under a favorable annual growth scenario of 5% for the rain fed agriculture sector, the country could face cereal deficits of up to 6.25 million tons by 2016 (MOWR, 2001). Thus, improving water productivity is considered to have major contribution to national food security.

Taking thermal and moisture regime in to consideration, Ethiopia is divided in to 7 and 32 major and sub agro ecological zones (AEZ), respectively. The arid and semi-arid major AEZ are characterized by a growing period of less than 45 to 60 days and covers 34.24% of the country land mass. The sub moist major AEZ has a growing period of 61 – 120 days and covers 16.61% of the country. The above-mentioned three AEZs, which constitute 50.85% of the country, are known for their poor agricultural performance mainly related with moisture deficiency. The moist, sub humid and humid AEZ have a growing period range of 121 – 180, 181 – 240 and 241 – 300 days, respectively and constitute 47.61% of the country. The remaining 0.82% and 0.76% of the country is under per-humid major AEZ and water body, respectively (MOARD, 2005). The productivity of rainwater is also low in the moist; sub humid and humid major AEZs due to the transformation of much of the rainfall to runoff (see section 2 above).

# 5. CURRENT STATE OF WATER USE IN THE AGRICULTURE SECTOR

## 5.1 Water Harvesting

### *5.1.1 In-Situ WH Measures*

***Soil and Water Conservation*:** Extensive soil and water conservation works have been implemented in many parts of the country since the 70's. Various types of SWC (In-Situ WH) measures were identified, designed and implemented for each type of land use and agro ecological zones of Ethiopia (Carucci, 2000, and field observation) (Annex 5-Table 5.1).

From field observation, the measures have resulted in reduction of field slopes and runoff rates. Besides, increased biomass production and recharge of aquifer and rising ground water levels were observed. Spring recovery and/or shallow wells have provided rapid and visible benefits to communities in desperate situation. In some valley plains, composed of either heavy clay soil or loose sandy /gravely soil, water table has gone up to a depth of 1 - 9 meter (personal communication with SWC experts in various parts of the country). Such source of water is being used for domestic water supply and irrigation. But, caution and measures were lacking to balance the mining and the rate of ground water recharge.

There are encouraging approaches to implement SWC on watershed basis in Ethiopia by the Bureaus of Agriculture in collaboration with many donors. One such program is the WFP supported MERET project. The project has supported 600 micro-watersheds (200 – 500 ha) on 74 moisture deficit Weredas to undertake SWC measures and area closure. There was remarkable achievement with the physical SWC measures while the performance of the biological measures was not satisfactory (WFP, 2005). In 2004, MERET estimated the moisture retention capacity of the sediment deposited behind/above each of the SWC measures on cultivated fields. The volume of the deposition wedge of the soil due to the existence of the structure was assessed and the resultant volume multiplied by the water holding capacity of the respective textural class. The total incremental soil moisture available within the conventional SWC measures was estimated to vary from 129 to 335 $m^3$/ha. This amount of moisture is made available in the soil at any one time after rainfall and can contribute to the crop's resilience to drought better than fields with no SWC measures. The crop's resilience to drought due to the presence of SWC measures was noticeable for up to 4 weeks after the rain (WFP, 2005).

On the other hand, due to the high intensity of rains coupled with the prevailing unsustainable land management practices on the upstream side, bunds and terraces are often overtopped and breached by the sediment-laden runoff water. Even in dry areas, the safe disposal of runoff water is a necessary complement to SWC measures designed to arrest runoff. In some cases, the SWC measures put in the farm land are not properly maintained.

***Spate Irrigation:*** In the moisture deficit highlands, farmers divert intermittent runoff from small creeks, road side ditches or cutoff drains in to their plots. In the lowlands, the farmers construct temporary diversions across seasonal streams by piling river bed material. Such structures are liable to damage by flood and have to be reconstructed many times in a single season. Beside to structural stability, the indigenous diversion structure could not help the farmers in diverting the required flow rate. Instead, they have to construct large size canals so as to enable them divert a large volume of water within a short period. Often such flow rate results in erosion.

***Lessons learned and best practices that could be shared with others***

Though no document on impact assessment was obtained, the positive contribution of the physical SWC measures (constructed on farmlands, hillsides and gullies) in retaining rainwater can be judged from the increased biomass production compared to non-treated areas. Thus, areas covered with SWC measures are worthy visiting.

The introduction of fruit trees as an integral part of the WH structures is increasing farmers' awareness on the value of water. Thus, focus has to be made on integrating high income generating crops with the physical SWC measures.

### *5.1.2 Other WH Measures*

### (a) Ponds

***Status and impacts in the sector***

Cistern and dugout ponds (for human and livestock water supply) are the dominant indigenous water harvesting structures used in many parts of Ethiopia for small scale irrigation and domestic and livestock water supplies. As of 2003 many small ponds with a capacity of $150m^3$ - $182m^3$ were excavated for the purpose of supplementary irrigation. The ponds were constructed by mobilizing people with support from the Government and NGOs. The ponds and water tanks (60 $m^3$) are owned by individual households, which make the operation and maintenance relatively simple.

***Effect on crop production***

Each pond provides water for a supplementary irrigation of 400-1000 $m^2$ plot. An EU supported evaluation showed that, with the provision of the essential agricultural and marketing extension support, sales from vegetables grown by the indicated pond size enables a household to purchase 30% - 80% of the annual food needs (Landell Mills, 2004).

***Support Needs***

The major challenges with the dugouts were the high seepage rate and high initial cost (35 – 75 Birr/$m^3$ of stored water or 4 – 8.6 US $/ $m^3$ of stored water) (Landell Mills, 2004) (Annex 5-Table 5.2).The ponds can not be financially attractive to supplement cereal crops due to the smallness of the irrigated plot size. For instance, if a 182 $m^3$ capacity pond is used to supply water for five supplementary irrigations of wheat planted on a 1000 $m^2$ plot the production could increase from about 160 to 260 kg (TBWRD and REST, 2002). In other words, the increment in production would be insignificant compared to the effort and cost required to construct a watertight pond. Thus, affordable interventions are required to rectify seepage.

The irrigation efficiencies considered in the design of ponds was 60% as conveyance loss was presumed to be negligible (TWRDB and REST, 2002). Irrigation efficiencies linked to the use of water in ponds were described by an EU evaluation mission as follows:

> "The irrigation methods used in most cases were flooding, basin or in some cases furrows (both level and sloping), or a combination of the three. As a result, the irrigation application efficiency was very low and could be around 30 – 40%. Where farmers used watering cans, to apply the water directly onto the plants, (….) conveyance and application efficiencies improved to around 60 – 70%. For the majority of other cases very low irrigation efficiencies were being achieved (20 – 25%)" (Landell Mills, 2004).

The above statement indicates the need for introducing measures that would improve the water use efficiency. No other information related to the issue was found.

### (b) Water Tanks

***Status and impacts in the sector***

Various concrete and masonry WH structures (each 60 $m^3$ capacity) were first constructed on a trial basis in the Rift Valley (Near Nazreth - Oromia) in 1997 (Rami, 2003). The trial site consists of deep sandy soil with very deep ground water table and torrential and erratic rains. The dome-shaped concrete tanks (costing Birr 5000 in 2001) and masonry hemispherical ponds (costing Birr 3500 in 2001) were disseminated to many parts of the country especially to food and water insecure areas. In 2002 – 03 many of such structures were built mainly in Amhara Region.

The merit of these structures, as observed from few successful ones, is that water loss due to seepage and evaporation is very low if properly constructed. Farmers extract water manually mainly using buckets/watering can and apply it directly to the micro basins of each tree, small furrows or to a drip system. The stored water is also used for domestic purposes and livestock when there are no better alternative sources.

Implementation of ponds and water tanks commenced at a massive scale in 2003. The accomplishment of these structures in the four main Regions of Ethiopia is shown in Annex 5-Table 5.3.

***Support Needs***

The demerit of the tank and masonry lined pond was their high initial cost especially in areas where sand is not available or transportation cost is very high. Besides, due to poor workmanship[19] the concrete structure cracked and consequently many tanks were observed leaking heavily. Another drawback was associated with the soil in which the tanks were erected. Though the dome shaped tanks were tested for deep sandy soil condition but were constructed on clay soil that expands after rains and contracts and cracks during dry times. Farmers tried to patch the cracks with cement but the cracks reappeared shortly after (Rami, 2003). For reasons associated with the cost and the poor technical performance, replication of these measures, on the own initiatives of the farmers, is rare. Therefore, there is a need for the identification and promotion of low cost but structurally safe and stable water storage.

[19] People with experience in mixing cement - sand – gravel and water at the required ratio and in plastering skills are very difficult to find in most rural areas. In most cases the basic rules of concrete curing were not observed.

### (c) Hand Dug Wells

Many hand dug wells with a depth of 1 – 9 meters are being used for irrigation, domestic and livestock water supply in many places. On average one hand dug well enables to irrigate 0.037 ha (MoARD, 2005). Water extraction means are bucket and rope, Shaduf, treadle pump, and to some extent motorized pump.

The constraints associated with the hand dug wells are the following (MoARD, 2005):

- Digging wells at very close spacing – leading to fast decline of the water table;
- Declining of water table and consequently farmers tend to increase the depth of the well;
- Wells are open and unlined - Collapsing of side walls of the wells during the rains and consequently widening of the top diameter of the well. As a result arable land is wasted;
- The frequent removal of caved-in soil from the well is tedious and competes with other agricultural activities of the farmer.

***Support Needs***

Upgrading the technical capacity of technicians is needed in areas related to locating well sites, lining wells and artificial recharging of the ground water.

## 5.2 Community Managed Irrigation Schemes in Ethiopia

Community managed irrigation schemes in Ethiopia can be viewed as those initiated by community and those by the government or NGOs.

### Indigenous Irrigation Schemes

***Status and Impact in the sector***

Most of the indigenous irrigation schemes were initiated many generations back (more than 100 years), according to members of the community (Annen C. 2001; IFAD, 2005). One can deduce from this that the importance of irrigation in Ethiopia has been recognized even when the population was small. The total irrigated land under traditional system is estimated to be about 138,000 ha and about 572,000 farmers are involved (FAO, 2005). (Note: the indicated sum of irrigable area is not consistent in various reports.) Sources of irrigation water are: streams, springs, shallow wells and ponds. Field observations made in most part of the basin show that a good number of the available perennial surface water sources are used fully or partially for irrigation, except those found in deep gorges or beyond the capacity of the community.

The indigenous irrigation schemes are characterized for their relatively better water utilization and enforcement of internal byelaws. This is attributed to the commitment of the members and the strength of the indigenous organizational structure. However, in some indigenous irrigation schemes, there are cases of water losses due to seepage and leakage at breached points along canal routes[20]. In many of the indigenous irrigation schemes water is delivered on long rotation period (15 – 30 days), due to the limitations in the stream flow rate and seepage along the canal. The farmers or the extension workers do not attempt to match the stream flow rate with the size of the irrigable area. As a result of the inadequacy of the applied irrigation water crop yield is often low; (yield of tomato, onion and carrot were in the range of 6.0 – 6.5 ton/ha (Tekeze basin Master plan study, 1998)). In some irrigation schemes, the size of irrigated area fluctuates from year to year due to the decline in the amount of the stream flow. The reduction in the amount of stream flow could be very severe following drought or low rainfall season.[21]

### ***Lessons from Indigenous Irrigation Schemes***

The organizational structure of the indigenous irrigation schemes has a vital role in the sustainability of the irrigation schemes. Thus, it is worthy considering taking lessons from it. Members of the user groups observe earnestly their unwritten byelaws and elected leaders. The members fully participate in maintenance activities and have a firm stand against water theft. Such attitude of the members is contrary to those in the Government/NGO initiated schemes.

## Government or NGO initiated Irrigation CMI Schemes

### ***Status and Impact in the sector***

During the last few decades government agencies and NGOs have intervened to develop new irrigation schemes and upgrade the indigenous ones by constructing diversion weirs, reservoirs, ponds, water tanks

[20] Pervious geologic formation and holes created by termites are often the responsible factors for seepage along canal routes. Lining canals is often unaffordable by the farmers.

[21] IFAD evaluation mission in September 2004 noted the worries of farmers in two upgraded indigenous irrigation schemes located in the headwaters of Tekeze that “the last rains had been too little and that the river flow was less than normal”.

and shallow wells. The area equipped for irrigation in 2002 was about 48,300 ha and about 74,100 farmers were involved (FAO, 2005).

Most of the Irrigation schemes initiated by the government or NGOs do not operate at full or design capacity. The major cause is lack of proper adequate extension support (Yaicob Likke, 2003; Landell Mills, 2004; IWMI et al, 2004 and IFAD, 2005). Another cause is shortage of water caused by reservoir sedimentation, reduced canal capacity (by siltation and weed growth) and/or excessive seepage from reservoirs and along canal routes. There are also signs of lack of ownership or dependency on the users' side resulting from failure to involve them from the onset. Often, resources are sought from the government and donors for the rehabilitation of the delayed maintenance work (IWMI et al, 2004). There is a general consensus on the importance of treating the catchment areas of irrigation schemes so as to maintain stream flows and reduce sediment inflow to reservoirs. However, little has been done to address the catchment areas and consequently there is fluctuation in the size of irrigable areas from one year to the other.

A constraint analysis conducted in 2003 by FAO on six irrigation schemes in Tigray and Amhara noted the following findings (Yaicob Likke, 2003):

On average, only 48% of the irrigable area had been developed. No efforts were observed to utilize the schemes to their full capacity.

Maintenance of canals and related structures was poor as a result of which loss of water due to seepage was very high.

Water management of the schemes was very poor which was partly due to poorly organized water user associations. This problem was explained by the following facts:

- Excess application of water at the plots situated at the upper most reach of the supply canal and water shortages in plots situated towards the tail of the supply canal.
- Water was delivered by rotation to each plot after long interval regardless of the crop water requirement.
- Water theft was observed.
- Canals were breached at many places to divert water to farm plots.

> Crop production under irrigation is intended to satisfy subsistence needs of households and does not reflect profitability of the crops. The dominant crops are of low yield and low value such as maize, chick pea, barley, wheat, *teff* etc. The proportion of vegetables and other high value crops was insignificant.

The above mentioned constraint analysis concluded that the factors responsible for the above mentioned limitations were associated with limitations in capacity (skill and finance), extension support, market, etc. Similar conclusion was also made by an IFAD evaluation mission (in September 2004) that extension support was lagging behind the construction of small scale irrigation schemes. Besides, it was also noted that limited market for vegetables crops, which form the main thrust of a diversification strategy, was the main challenge to the achievement of commercializing irrigated farming (IFAD, 2005). The later is an essential strategy for improving water productivity. Because, irrigation schemes close to big urban markets and along main highways are observed to utilize their land and water resources effectively and subsequently gain good return.

### Irrigation Efficiency in CMI Schemes

Irrigation efficiency considered in the design of irrigation schemes in Ethiopia is 50% - 60%. The basis for adopting such irrigation efficiencies was referred to the recommendations in the FAO publications (personal communication with practitioners).

A one time field measurement undertaken to determine conveyance and application efficiencies in three community managed irrigation schemes in the Tekeze basin – Tigray Region - reveals low figures (34 – 54%), (Annex 5-Table 5.4).

The water lost along the conveyance system does not only cause water shortage in the schemes but also water logging of the arable lands along the lower side of the canal (Annex 5-Photo 5.1).

From field observation, there are indigenous practices that appear to involve high irrigation efficiencies in SSI (Leul, 2004). These practices need to be addressed by researchers. Some of them are the following:

- Length of furrows in SSI schemes is short (on average 5 – 20 m). Water is delivered to the furrows from temporary field canals/ditches, which also irrigates the field in the mean time. The temporary field canals are plowed over the next season;

- Furrow ends are closed and thus no water is lost as runoff. Water application in to the furrows is stopped when water is about to spill over the ridges of the furrow;

- In some areas small level basin with a width of 1 – 2 meter and length of 2 – 15 meter are used to irrigate vegetable crops. In sloppy areas, these basins form a series of bench terraces, but are plowed over the next season. Water application is stopped when water is about to start spilling over the ridges of the basins.

On the other hand, there are also practices that tend to reduce the water use efficiency, such as the following:

- Canals are breached at many points so as to take water to individual plots. But, as the breached points are not sealed properly water is lost by leakage.
- Adjacent plots are planted with different crops at different times. In such cases the supply canal is required to convey variable amount of irrigation water during the growing season in response to the variable demand. However, there is no mechanism to quantify the demand and regulate the flow rate accordingly. Often, unregulated flow is released to the plots located haphazardly in the system and water is lost consequently. The major loss of water occurs at the beginning and towards the end of the irrigation season in connection with the release of excess water to plots located haphazardly in the system.
- In addition to seepage (due to pervious formation), water is lost by spilling over canal banks caused by reduced canal capacity resulting from sedimentation and growth of weeds in the canal.

The impact of irrigation on the individual farm household in terms of food security and incremental income is the single most important factor determining project success and sustainability, yet this information was not available in any document. The major constraint for not having such information is the lack of a coherent monitoring and evaluation.

***Support needed to make CMI systems more efficient and productive***

Most of the problems in CMI are linked mainly to lack of adequate skill and knowledge in agronomy, water management and marketing. The absence/weakness of the WUAs is also a major drawback. Thus, in addition to establishing and/or strengthening of WUAs, there is a need for upgrading technical capacity of technicians.

Some of the practices indicated above appear to have positive attributes but are not yet picked or recognized by the research and extension systems. This calls for initiating a task aiming at identifying and characterizing best indigenous practices with a potential of improving water productivity.

The research and extension systems need support to establish systematic implementation and monitoring and evaluation procedures.

The indigenous irrigation schemes require structurally stable and effective diversion and conveyance structures.

## 5.3 Overview of Public Irrigation Schemes in Ethiopia

***Status and Impact in the sector***

PMI are categorized as the large (>3000 ha) and medium (200 – 3000 ha) irrigation schemes (MOWR, 2001). The PMI schemes comprise an area of about 97,700 ha and are owned and operated by public (government) enterprises (FAO, 2005)[22].

Public irrigation schemes started in Ethiopia with the development of the Amibara irrigation project (MOWR, 2001). About 10,285 ha of land were brought under gravity irrigation by the end of 1982. However, after 5 – 8 years of operation 40% of the irrigated farm was abandoned due to salinity caused by poor drainage[23] and lack of appropriate water management system (Girma T. and Fentaw A. (*ND*)). Other large public irrigation schemes that have been initiated towards the end of the 80s, but suspended in the 90s are the Gode West, Ommo Ratti and Alwero Abobo. A total of 21,000 ha irrigated state farms in the Awash and Rift valleys were abandoned / suspended during 1992 – 1998. The reasons for this were the need to reallocate land from the public sector to peasant farmers, problems associated with poor management and inappropriate operation and maintenance, loss of land due to soil salinity and flooding problem (Annen, 2001).

[22] http://www.fao.org/ag/agl/aglw/aquastat/countries/ethiopia/index.stm
[23] The farm development did not include the construction of drainage system.

Out of the 64,352 ha irrigated by 41 schemes in the Awash River Basin, a total of 2,126 ha are reported to be affected by salinity. The heavily affected one is Melka Sedi irrigation scheme where out of the 3047 ha irrigable land about 38% or 1165 ha was affected by salinity.

Fincha sugar plantation (6500 ha) is the only large scale public irrigation scheme located in the Nile basin that is operating successfully (MOWR, 2001; Metaferia Consulting Engineers, et al., 2002).

Document showing the impact attributed to PMI was not found.

**Water Use Efficiency in PMI schemes**

Water use efficiency data for Fincha sugar plantation was not found except that it is using both sprinkler and surface irrigation methods. Estimates of irrigation efficiencies for surface irrigated PMI in the Awash River Basin were in the range of 30 – 55% as per the record of 1989 (Annex 5-Table 5.5).

***Support needed to make PMI systems more efficient and productive***

The poor management of the irrigation water in the PMI is not only causing wastage of water but also loss of land due to salinity. The managers and technical personnel of the PMI schemes may need to upgrade their knowledge and skill. Besides, the option of management transfer to the private sector could also be considered.

## 5.4 Overview of Private Irrigation Schemes

Private irrigation schemes range in size from 0.5 ha to 200 ha and have been reemerged in the early 90s resulting from the market based economic policy in the country. Up to 2002, total area under Private Managed Irrigation Schemes was 6,000 ha (MOWR, 2001).

Recently, the private sector is involved in the establishment of greenhouses to grow flowers for export.

Apart from this, document containing additional information on private irrigation schemes was not found. However, these schemes do have relatively better management as compared to the public managed irrigation (personal observation).

# 6. POTENTIAL INTERVENTION AREAS

## 6.1 Establishment of Data Base

The relevant government institutions possess very little information related to the subject in question and yet not properly organized. The inadequacy or lack of data, related to agricultural water use, is among the major constraints noted in various papers prepared by researchers, planners and designers. There is also a gap in formal and systematic information exchange mechanism among institutions and within an institution. Thus, the EWUAP has to address the establishment of database on the use of water for rain fed agriculture, irrigation and livestock. This should include establishing a mechanism to continuously update and avail the data/ information to users.

## 6.2 Upgrading Technical Capacity

All of the directly involved stake holders (farmers, WUAs, extension agents and researchers) have capacity limitations. The lack or inadequacy of research and extension support that aims at maximizing the productivity of water is recognized as key constraint in Ethiopia. Therefore, research and extension institutions need to be strengthened to fully identify the potentials and constraints on the use of water for agricultural production in each agro ecological zone of the country. Both extension and research institutions have to be able to identify and promote best practices on maximizing water productivity. Devising and implementing mechanisms for scaling-up of best practices is required. To this effect, training needs assessment has to be conducted regularly followed by the preparation and implementation of appropriate training/skill transfer programs.

There is a strong need for the establishment and empowerment of WUAs in all parts of the country. Such effort requires blending lessons from indigenous organizational structures and contemporary management skills.

Attempts were made to identify training needs by Annen (2001) and Awulachew et al. (2005) taking input from stakeholders involved in agricultural water use in many parts of Ethiopia. The proposed training areas identified are compiled as follows:

i) **Research and extension training areas in rain fed agriculture**

Integrated watershed management that includes measures to achieve the following:

- Supplemental irrigation for dry spell mitigation
- Enhancing soil infiltration
- High yielding, early maturing food, feed and commercial crops,
- Crops suitable for harsh (low rainfall, shallow soil depth) environment

ii) **Research and extension training areas in Irrigated agriculture**

Developing irrigation extension package and establishing a system for periodic monitoring and evaluation of the package. The package need to include, but not limited to, the following components:

- Irrigation agronomy of major crops;
- Development of intensive high value cropping patterns;
- Introduction of improved seeds of food crops and cash crops;
- Soil fertility management (crop rotation with leguminous crops, use of organic manure, fertilizer application);
- Integrated pest management (IPM);
- Introduction of low volume irrigation techniques;
- Monitoring and control of land degradation (erosion, soil salinity and alkalinity);
- Irrigation scheduling, water allocation and distribution; and
- Operation and maintenance of canals and related structures.

iii) **Interventions Related to Water User Association**

- Community based irrigation scheme management;
- Formation and strengthening of water users' associations;
- Cooperative management;
- Crop storage and post harvest handling of various farm products;
- Administration of saving & credit schemes and revolving funds;
- Market information management;
- Monitoring of cooperative marketing; and
- Construction of cooperative stores.

## 6.3 Policy/Strategy Intervention Areas

There are no rules and regulations that ensure sustainable use of water. No one can control the diversion or pumping of water upstream of an existing scheme or enforce proper operation and maintenance of schemes. Poorly maintained canal systems, excessive water diversion and application, water theft, the perception of water as a free commodity etc. are among the factors contributing for the low productivity of water. There is no water charge system in the country except in the Awash State farms. The absence of such regulatory measures is attributed to capacity limitations.

Thus, EWUAP could assist the relevant agencies in the development and implementation of strategies and practices for the improvement of water productivity in agriculture. Issues to be addressed in this regard would include, but not limited to, the following:

- Enforce integrated watershed development approach;
- Establish and enforce water use right;
- Establish and enforce water charge;
- Enforce proper operation and maintenance of irrigation schemes;
- Enhance private sector involvement in the sector;
- Ensure sustainability of standardized activities; and
- Ensure stability of institutional arrangements.

## 6.4 Adaptive Trials of Best Practice

### *6.4.1 Irrigation under a Condition of Water Scarcity*

In many places of the country it is common to see moisture stress and stunted growth of irrigated crops. This was attributed mainly to the prolonged irrigation interval and water shortage caused by using the small amount of water available in a stream/pond/well to irrigate a relatively larger plot. Thus, the actual fact in the ground is calling for adaptive research on deficit irrigation.[24] Research on vertisol in the Middle Awash Valley of Ethiopia showed the possibility of getting the same cotton yield and saving of 40 – 50% of irrigation water by applying three irrigations, one of 200 mm at planting, followed by two of 150 mm each at flowering and ball formation as compared to the 75 mm irrigations at 2 weeks interval, (which was considered as the best practice for getting maximum production) (Jutzi et al. (eds), 1988).

[24] A research conducted in Italy on deficit irrigation on Tomato has shown that seasonal water supplies ranging from 20-60% of full irrigation yielded 70-90% of maximum marketable yield (ICID, 2002).

### *6.4.2 Addressing Dry Spells to Improve Rain fed Productivity*

As pointed out in section 2 of this report, rain fed agriculture in most parts of the Ethiopia is subjected to moisture deficiency induced by many factors such as intermittent dry spells and/or shortage of rainfall. A study that show the effect of dry spells and early stoppage of rain on yield reduction in Ethiopia was not found. However, studies carried out outside of Ethiopia, and applicable for all semi-arid tropics, indicated that dry spells cause a decrease in yield by about 70% or some times a total crop failure (McHugh et al, 2004 adopted from Rockstrom[25] et al, 2002).

Under the practice of supplementary irrigation, all of the harvested water is utilized during the rainy season and up to two months from the end of the rain season, whereas, with double cropping system the stored water has to be utilized over eight months from the end of the rain season. The difference is that the practice of supplementary irrigation enables to utilize the water that could have been lost as evaporation and seepage in the longer storage period. Thus, water use efficiency could increase if all of the harvested water is utilized only for supplementary irrigation.

### *6.4.3 Increasing Tillage Depth in Clay Soil*

Enhancement of rainwater infiltration through breakage of the plow pan is becoming necessary according to some practical works in the field. EWUAP should capitalize on this practice.

### *6.4.4 Water Use Efficiency in a Field with Short Furrow Length*

Many SSI schemes in Ethiopia were designed to operate with a furrow length of 50 – 100m. However, the prevailing furrow length is in the range of 5 - 20m with closed ends (Annex 6-Photo 6.1). According to the farmers, the reason for using short furrow length is that it allows uniform water distribution in the field. At a glance, one could feel that the difference in infiltrated volume between the head and tail of these short length furrows could be small. The disadvantages of short furrow length is that labor requirement is higher compared to longer furrows; secondly short furrow length requires longer distribution system and hence more conveyance losses. (Could the water lost in the “conveyance system” be accounted as used by the crop?)

Therefore, the merit and demerit of the irrigation practice with short furrow length has to be examined.

[25] Rockstrom, J et al., 2002. Rainwater Management for Increased Productivity among Small-Holder Farmers in Drought Prone Environments. Physics and Chemistry of the Earth. PP 949 – 959.

### *6.4.5 Treating Catchment Areas*

Irrigation schemes and rain fed agricultural areas cannot be sustainable without addressing issues and problems at their respective catchments. On the other hand, the catchment areas are connected with the livelihoods of the community. Thus, treating the catchments would imply addressing the livelihoods of the community who are subsistence farmers. The needs of such farmers are interventions that could bring quick and visible benefit. The interventions implemented to date were of long term return and thus in conflict with the interest of the upland community. Farmers used to express their objection to the technologies by encroaching to closed and afforested areas. Therefore, the following points, among others, need to be considered for the sustainability of irrigation schemes:

- Could there be a fast growing, high yielding and nutritious fodder grass or shrub that can grow under harsh environment. The harsh environment could be explained in terms of little rainfall and long dry period, poor soil fertility and shallow depth, etc.
- What kind of fast growing flowering shrubs can be introduced to enhance apiculture in the catchment areas? Shrub varieties with different period and length of flowering can be considered so as to ensure continuous supply of nectar to the bees.
- Could there be a benefit sharing mechanism between downstream water users and care takers of the watershed?

### *6.4.6 Technologies for a Condition under Temporary Water Logging and Dry Spells*

Water productivity could also be increased by Identifying crop varieties that could withstand the temporary water logging instead of focusing only on disposing the precious rainwater. Besides, there is a need to identify crop varieties and management practices that would be able to cope up with the sporadic dry spells.

### *6.4.7 Identification and Promotion of High Value Non-Food Crops*

#### (a) Addressing Neglected Non-Food Commercial Crops

Another means of increasing water productivity would be to identify and promote the production of crops with a potential for high economic return, but that are currently neglected for lack of knowledge or market outlet.

Aloe and sisal are among the economically important and yet neglected plants growing in many parts of Ethiopia. Aloe grows in moisture stressed and marginal areas as weed (Annex 6-Photo 6.2). Its ability to grow with little moisture and on infertile land makes the aloe plant as a potential SWC measure. Besides, many documents indicate that aloe is grown commercially in many parts of the world for its use in medicine, cosmetics, and health care industries. But, it is not yet recognized by the Ethiopian researchers and farmers as an important crop with a potential in diversifying the economy of the moisture-stressed low lands.

Sisal plants are growing in the low land and highland areas with mean annual rainfall of over 500 mm. Except for a couple of state farms; sisal is grown as live fence around homesteads and farms and on marginal areas (Annex 6-Photo 6.3).

Currently, both aloe and sisal have little or no economic significance. Dried aloe is used as fuel wood or fumigating domestic liquid containers in some parts of the country. Sisal is used to make ropes for own use by farmers. On the other hand, jute is being imported for fabricating grain sacks.

Thus, in view of improving water and land productivity, there is a need to consider the production and processing aspects of aloe, sisal and other plants naturally grown under harsh environment.

### (b) Promoting Low Water Demanding Commercial Crops

Availability of water is a critical factor over a large portion of Ethiopia. According to MoARD, the area under arid, semi-arid and dry sub-humid of Ethiopia is estimated as 42.3, 2.9 and 19 million ha, respectively (MOARD, 2005). These areas are used for pastoral grazing, grazing and cultivation and cultivation, respectively. These areas could be a potential area for testing commercial plants like Jojoba, which is known for its ability to survive in a harsh desert environment.

AMAREW project is noted to work with ARARI's Adet and Sirinka agricultural research centers to promote *Vernonia Galamensis*, a potential oil crop of industrial use such as plasticizers and paint additives. This plant is a widely distributed weed in Eastern Africa, including Ethiopia. The Adet Research Center has identified two high yielding *Vernonia* varieties (Brhane et al, 2005).

### *6.4.8 Determination of Site Specific Rainfall-Runoff Relationship*

In the process of designing water-harvesting structures, the value of the runoff coefficient, which is developed as a function of catchment characteristics, is obtained from textbooks[26]. The Runoff coefficient used in determining WH ponds in Northern Ethiopia was 0.5 (Landell Mills, 2004). Although not without merit, the attempt to directly adopt design parameters developed for other geographical location involves serious errors.

Overestimation of the runoff coefficient could result in expending unnecessary cost. Similarly, underestimation of the runoff coefficient results in reduced irrigable area size. Therefore, it is necessary to conduct hydrological research to determine rainfall – runoff relationship for representative land use and cover, climatic, topographic and geologic conditions.

[26] In the design of small reservoir dams, a runoff coefficient of 0.2 – 0.3 was used in many parts of the country.

# 7. BENCHMARKS FOR MONITORING AND EVALUATION

All of the documents reviewed couldn't provide adequate information to establish quantitative benchmarks of the best management practices. In view of this, the following table is prepared so as to initiate discussion among the stakeholders and thereof establish site specific and appropriate benchmarks (Table 1). The proposed indicators are applicable to all water use categories.

**Table 1:** Potential Bench Marks for Monitoring and Evaluation of Project Performance

| Applicable Water Use Category | Indicator | Data Source | Current status/level |
|---|---|---|---|
| WH, CMI and PMI | Establishment and maintenance of data base | MOARD, EARO, MOWR | Scanty and unorganized data; difficult to access; Information in river master plans need updating |
| WH, CMI and PMI | Institutionalizing Water Management research and extension | MOARD, EARO | Very few localized research; |
| WH, CMI and PMI | Yield at national level | CSA | Yield data available in yearly statistical abstracts of CSA and from EARO |
| WH, CMI and PMI | Tons of produce (by type) per mega liter of irrigation water applied | MOARD, EARO, MOWR | Baseline data to be collected from sites, with similar soils and agro ecology selected for monitoring |
| WH, CMI and PMI | Area coverage of newly introduced best practices | MOARD, EARO | Base line data need to be collected |
| WH, CMI and PMI | Improvements in cropping intensity and cropping productivity | MOARD, EARO | Base line data need to be collected |
| WH, CMI and PMI | Recharge of groundwater enhanced | MOWR | Base line data on depth and yield of wells, springs and streams need to be collected |
| WH, CMI and PMI | Trends in environmental degradation/Conservation | MOARD, EARO, EPA | Data in the master plans need to be updated and used as base line data |
| WH, CMI and PMI | Adoption of integrated watershed management approach | MOARD, EARO, MOWR | No coordination of efforts even within the same ministry |
| WH, CMI and PMI | Formulation and implementation of rules and regulations related to water rights, fee, operation and maintenance | MOARD, EPA, MOWR | Rules and regulations related to water rights, charge, O&M do not exist |
| WH, CMI and PMI | Technical forum at all levels held regularly | MOARD, EARO, MOWR | No regular technical forum |
| WH, CMI and PMI | Irrigation water use efficiency enhanced | MOARD, EARO, MOWR | 30 – 50% (collection of site specific data is required) |
| WH, CMI and PMI | Irrigation water is delivered on volumetric measurement | MOARD, EARO, MOWR | Base line data need to be collected |
| WH, CMI and PMI | Records of irrigation volumes used per hectare by water efficient farmers | MOARD, EARO, MOWR | Baseline data to be collected from sites, with similar soils and agro ecology selected for monitoring |

# 8. INSTITUTIONAL AND LEGAL FRAMEWORK ARRANGEMENT

## 8.1 Institutional Arrangement

### *8.1.1 Federal Level*

*Ministry of Agriculture and Rural Development*

The ministry of agriculture and rural development is responsible for extension service related to SSI, WH, SWC, irrigation agronomy, crop protection, marketing and others. Besides, the MOARD is responsible for the planning and implementation of small scale irrigation and water harvesting schemes.

*Ministry of Water Resources*

The Ministry of water resources is responsible for all water development issues including overall planning, development, management utilization and protection of the country's water resources. It is also responsible for the task of developing a national policy and strategy, issuance of directives, standards and guidelines and allocation of water resources among the different uses.

*Cooperative Promotion Commission*

The establishment and strengthening of WUAs and service cooperatives is the responsibility of the cooperatives promotion commission in collaboration with the offices at the lower administrative level.

*Environmental Protection Authority*

EPA is responsible for the preparation of environmental protection policy, laws and directives as well as evaluating and monitoring the impact of irrigation and other projects on the environment.

*Ethiopian Agricultural Research Organization*

The Ethiopian Agricultural Research Organization (EARO) is a federal institution responsible for conducting and coordinating agricultural research activities across the country. The regional research centers, controlled by their respective regional governments, have the responsibility to address specific local and regional (provincial) problems.

The objectives of EARO are to:[27]

- Generate, develop and adopt agricultural technologies that focus on the needs of the overall agricultural development and its beneficiaries.
- Co-ordinate research activities of agricultural research centers or higher learning institutes and other related establishments which undertake agricultural research on contractual basis.
- Build up a research capacity and establish a system that will make agricultural research efficient, effective and based on development needs.
- Popularize agricultural research results.

### *8.1.2 Regional (Provincial) Level*

During the period 1995 – 2003/2004 the design and construction of irrigation schemes in Tigray, Amhara and SNNP was conducted by the commissions known by the acronym COSAER. The extension support related to irrigation agronomy and water management was the responsibilities of the bureaus of agriculture in the respective regions. In Oromia region, the design, construction and extension support related to irrigation schemes was handled by OIDA.

As of 2003/04 the commissions in Tigray and Amhara were reorganized into Water Bureaus and are responsible for the implementation of irrigation infrastructure. In SNNP region, Southern Irrigation Development Authority is the successor of COSAER. The regional Bureaus of Agriculture and Bureaus of cooperatives promotion are similarly structured in all regions and are responsible for the irrigation extension support except in Oromia, where OIDA is the responsible organ. Their extension system reaches down to the communities (*Kebele, Tabia*) where supervisors and development agents are assigned. Irrigation experts are placed at *Woreda* level.

[27] Source: unpublished document from EARO

## 8.2 Legal Framework

***Proclamation No. 456/2005*,** defines obligations of rural land users, and land use restrictions. Protection of land becomes an obligation and failure to protect can lead to loss of title. Free grazing in areas with SWC is prohibited and appropriate SWC measures are required for all lands of <30% slope. Cultivation on slopes of 31-60% slope requires bench terraces. Slopes of >60% cannot be used for either cultivation or free grazing. Closure of degraded lands, and compensation for prior users is provided for.

***Proclamation No 197/2000***, states that all of the country's water resources are the common property of the Ethiopian people and the state and giving the MoWR the necessary power to allocate and apportion water to all regional states regardless of the source and location of the resource.

***Proclamation No 4/1995***, states that the MoWR has the power and duty to determine the conditions and methods required for the optimum allocation and utilization of the water that flows across or between more than one regional government or among various users.

***Proclamation No 41/1993***, granting the regions the mandate for certain aspects of water resource management.

***Proclamation No 197/1992***, dealing with the water resources management regulations describing development areas that require a license, procedures for obtaining licenses, the allocation of water for various uses and the need to protect water resources from pollution. It considers that water is an economic good and that it has to be valued and deserves protection.

# 9. POLICY/STRATEGY DEVELOPMENT WITH RESPECT TO EFFICIENT WATER USE

## 9.1 Rural and Agricultural Development Policies and Strategies[28]

The rural development policy, issued in 2001, is an extension of the basic economic development goals set by the Ethiopian government. The rural development policy presents issues and strategies that would ensure rapid and sustainable growth by utilizing the rural population and the abundant land resources. The policy also considers non agricultural development activities including the wide range of infrastructure and social development activities.

The core elements of the rural development policy are the following: extensive use of human labor, proper use of land resources, approaches compatible with different agro ecological zones, integration, capacity building, improvement of agricultural marketing and rural finance, expanding rural infrastructure, etc. Details of those directly related to EWUAP are shown below:

### *9.1.1 Improving Utilization of Water Resources*

Bringing change of attitude towards improved agronomic practices of Ethiopian farmers is considered as the starting point for implementing measures towards proper utilization of the country's water resources. Focus is made on the need for adopting strategies that will enable conserve and control rainwater and improve its utilization. Besides, there is a need to make use of simple technologies, which can be devised by farmers themselves, to conserve runoff and flood water and use it for irrigation. Medium-size river diversion and dam construction are also options considered in the strategy.

### *9.1.2 Improving Productive Capacity of Farmers*

The agricultural development strategy is based on building the productive capacity of the farmers and enable them improve their productivity through the provision of agricultural extension and advisory service on a continuous basis. To this end, the specific strategy is to train DAs in agricultural skills at agricultural vocational training centers for three years. Out of those trained under such schemes at least

[28] Source: FDRE 2001. Rural Development Policies, Strategies and Instruments. Ministry of Information, Addis Ababa, Ethiopia

three (one each in agronomy, livestock, and natural resources and irrigation), will be assigned to each farmers' association areas.

The strategy also focuses on strengthening agricultural research so as to generate appropriate technologies that would lead to productivity improvement and sustainability. The technologies to be adopted need to be compatible with the specific requirements of the different agro-ecological zones in the country. In drought prone areas, the strategy emphases for the improvement in water resource development and utilization, natural resource protection and others. In areas with adequate rainfall, development efforts are planned to focus on all-year-round cropping and improvement of water utilization.

## 9.2 Water Resource Management Policy and Strategy

The national water resources management policy of Ethiopia (MOWR, 1999), aims at enhancing and promoting efforts towards an efficient, equitable, and optimum utilization of the available water resources and contributing to the country's socioeconomic development on sustainable basis. The guiding principles of the policy are:

(i) recognition of water as a scarce and vital socio-economic resource;
(ii) recognition of water as an economic good;
(iii) stakeholders to be involved in water resource management.

The irrigation policy, which is part of the water resources management policy, among other things emphasizes:

- Full integration of irrigation with the overall framework of socio-economic development plans;
- Decentralization and user-based management of irrigation systems, considering the special needs of the rural women;
- Developing priority schemes based on food requirements and the national economy,
- Supporting and enhancing traditional irrigation schemes;

The water sector strategy was developed in 2002 and stems from the water policy and incorporates the following strategic points among others (MOWR, 2002):

- Harvest rainwater through the construction of structures to meet domestic water supply and irrigation needs at local levels;
- Devise and implement demand management measures such as pricing, improved extension services, public awareness, and regulatory measures that improve efficiency and conserve water resources;
- Undertake SWC measures that reduce soil erosion and reservoir siltation;
- Encourage and promote local community participation in watershed management and water conservation measures and practices;
- Asses technical capacity gaps, develop training programs to bridge them, and implement these programs;
- Establish tariff structure for water services based on site-specific characteristics of the schemes, and ensure that water prices lead projects to full cost recovery;
- Promote, build and strengthen partnerships between community, government, private sector, and external support agencies. For this purpose, establish mechanisms such as, water committees, water boards, and water user associations, professional and civic associations;

# 10. KEY STAKEHOLDERS FOR THE PROJECT

## 10.1 Associations and Cooperatives

### (a) Water Users Association

Formal WUAs and informal/traditional community groups are responsible for the water management of CMI schemes. In CMI schemes constructed as of 1995, WUAs were organized prior to the completion of construction works. The irrigation scheme is then handed over to the WUA. Concurrently, the executive committee members of the WUA are trained in some basic irrigation operation and maintenance aspects. Then the WUA is made responsible for overall management of the irrigation scheme. However, after the transfer of management responsibilities to the WUA the irrigation water management efficiency decreased due to the lack of the necessary extension support (IWMI et al., 2004).

### (b) Service Cooperatives

Service cooperatives are engaged in the supply of fertilizers and other inputs.

### (c) Professional Associations

- Ethiopian Rainwater Harvesting Association (ERHA), Addis Ababa. Ethiopia; Founded in 1999
- Agronomy and Crop Physiology Society of Ethiopia (ACPSE)
- Crop Protection Society of Ethiopia (CPSE)
- Ethiopian Civil Engineers Association
- Ethiopian Society of Soil Science (ESSS)

## 10.2 NGOs and Donor Agencies

The Relief Society of Tigray (REST) and the Organization for Rehabilitation and Development in Amhara (ORDA), are local NGO’s involved in watershed management and the design and construction irrigation schemes. They are also engaged in the provision of limited extension support in irrigation development. Both agencies have acquired considerable expertise and capacity in irrigation development. In the Oromia and SNNP regions, the Lutheran World Federation (LWF) was the major NGO involved in irrigation development. The Ethiopian Evangelical Church Mekane Yesus (EECMY), Oromia Self Help

Organization (OSHO), World Vision, SoS Sahel, Food for the Hungry and others were also involved in irrigation development (Annen, 2001, Awulachew et al., 2005).

The donor agencies involved in supporting SSI and WH in various parts of the country are the following: WB, SIDA, USAID, GTZ, CIDA, IFAD, ADF, JICA, CRS, FAO, Irish Aid, (Awulachew et al., 2005)

### 10.3 Universities

- Mekelle University, Mekelle, Tigray;
- Debub University, Awasa, SNNPR;
- Arba Minch University, Arba Minch, SNNPR;
- Alemaya University, Alemaya, Oromia
- Addis Ababa University, Addis Ababa

## 11. BEST PRACTICES RELATED TO EFFICIENT USE OF WATER FOR AGRICULTURAL PRODUCTION

Many indigenous and introduced best practices and opportunities are believed to exist in many parts of the country. However, it was challenging to get documentation pertaining to the subject. This calls for continuous assessment and compilation of such practices with the participation of all stakeholders. Some of the readily available ones are presented hereunder.

### 11.1 Konso Indigenous Land Management Practices

Konso is mountainous area characterized by rugged and stony terrain, irregular rainfall and with soils highly susceptible to erosion. Conversely, over many generations the Konso people have developed an elaborate system of terracing, water conservation practices, irrigation, and multiple cropping systems with the integration of livestock and forestry and crop biodiversity (Foerch W., 2003) (Annex 11-Photo 11.2).

### 11.2 Ground Water Mining and Recharging in Wukro Wereda – Tigray

In the Abreha Atsbeha catchment many SSI schemes are operational using over 700 productive shallow wells. Except for the first 50, the users have carried out the site selection and construction of the remaining wells. The average distance between consecutive wells is 25 – 40m. Sixty person-days are required to dig a 4.5m deep well with top and bottom diameter of 3m and 2m, respectively.

Water abstraction from the wells is done using either treadle pumps or bucket. The size of land irrigated per well ranges from 0.25 – 0.75 ha (personal observation).

With the intention of recharging the ground water, the beneficiaries have implemented SWC works on the catchment. Terraces and trenches were the dominant measures carried out in the hillsides. Trenches were dug at the foot of the hills, which consist of sandy soil.

With the intention of harvesting the runoff that escapes from the abovementioned SWC measures, the community also constructed a series of percolation ponds along the creeks starting from the foot of the hillsides.

At one time Tigray Water Resources Development Bureau had initiated to monitor the status of the ground water on 100 wells in the area with technical support from WHIST (a project financed by CIDA).

## 11.3 Raya Plain Spate Irrigation

Farmers in the lowland plains of Raya Azebo, Alamata and Kobo Woredas heavily depend on the intermittent runoff generated from the highlands for growing crop. There are many diversion points along every dry creek that drains the highland. The diversion weirs, canals are constructed repaired/maintained by the users who are governed by their internal byelaws. Every plot gets a large volume of water within 30 – 60 minutes at a time. For the purpose of attaining uniform water distribution, farmers construct and maintain level bunds at a spacing of 5 – 10 m (personal observation). In flat fields, only temporary bunds are constructed to reduce runoff from the field and increase infiltration.

## 11.4 Bishan Behe (Dire Dawa) Spate Irrigation

Bishan Behe farmers, like many others else where in the country, practice spate irrigation by diverting runoff water from the nearby dry watercourse to the cultivated land. Water is diverted into benched cultivated fields whenever additional moisture is needed. These level structures are very suitable for water distribution. They use level furrow to conserve moisture within the benched (leveled) cultivated fields (Annex 11-Photo 11.1). Out of the 423 ha cultivated land 309 ha (73%) was treated with various SWC measures. About 15 ha of gully and rill affected land have been reclaimed and brought back into cultivation. Because of the conservation works at the upper lying landscape, the downstream area has been protected and the groundwater recharged. Farmers are able to dig shallow wells and utilize the water for irrigating vegetables during the dry season (WFP, 2004).

## 11.5 Water Harvesting and Best Agronomic Practices in Hararghe Highlands

Sorghum and maize intercropped with pulses and sweet potato are grown in many parts of the Hararghe highlands. SWC measures such as terraces and tied ridges are used to conserve moisture and soil. In several parts of the area animals are kept close to homesteads and zero grazing is practiced (WFP, 2004). Zero grazing implies avoiding destruction of SWC measures by livestock, avoiding compaction of the land by livestock thereby reducing runoff rate, etc.

## 11.6 MERET Project Assisted Interventions

The project called "Managing Environmental Rehabilitation in Transition to Sustainable Livelihoods (MERET)" within MoARD, and supported by WFP is involved in the promotion of watershed management. The project is concerned at farm level with conservation, intensification, expansion of cultivated land, and diversification of income opportunities (WFP, 2005). The project introduced the Local Level Participatory Planning Approach (LLPPA).

The major activities of the MERET project include: terracing of farmland and hillsides; the stabilization of bunds and gullies; production and plantation of seedlings; area closure; construction of cutoff drains, waterways, access roads, ponds and spring development. Recently the project has expanded its activities to include water-harvesting structures (cisterns, micro basins, eyebrow terraces, herringbones etc) for crop production, fruit tree growing and to improve survival rates. Forage seeds, of local and improved varieties, have been produced in seed multiplication sites and distributed to project areas (WFP, 2004). Various guidelines are prepared to assist DAs in the implementation of the abovementioned structures.
Commendable efforts are being made by the MOARD by posting salient features of selected technologies and approaches on the web – www.wocat.net

Successful SWC works exist in Ambasel, Kalu, Wukro, Omo Sheleko, Chencha, Gorogutu, Dessie Zuria, Adet Nadear Weredas (Gete et al 2006). In many of these sites physical and biological SWC measures are integrated with forage, fruit tree, and/or other high value crops (such as sugar cane, cassava etc.). Farmers in Chencha and Omo Sheleko Woreda have adopted successfully the production of apple fruit using shallow hand dug wells introduced by MERET project (Gete et al., 2006).

# 12. CONCLUSION AND RECOMMENDATIONS

The country is endowed with plenty of rainfall and water resources. The government has established favorable policies and strategies and organized the extension system up to the grass root level with water considered as the entry point to transform Ethiopian agriculture. There are pockets of indigenous and introduced best practices scattered throughout the country and could be used as nuclei of development. The research system and some projects have also generated some technologies that would improve water productivity. However, the available opportunities, including the enabling policy environment, are not tested fully to their potential. And yet, the research and extension systems often externalize the factors constraining the improvement of water productivity.

Through the years, staff of the research and extension systems have organized and participated, repeatedly, in various technical workshops and in-service trainings. Many of them also received high level education within the country and abroad. The training program is still continuing. On the other hand, capacity limitations and lack of integration and coordination within and among institutions were ascribed as key constrains to the improvement of land and water productivity.

It has become evident that having regular technical forums at all levels (community, *Wereda*, Region, and Federal) would be instrumental in the exchange of best practices and monitoring of progress. Concurrently, it would also be important to devise mechanisms to ensure the effectiveness of the training and/or workshops.

The needs and intervention areas presented in this report are in congruence with those presented in the country report, project document, project implementation plan and project appraisal documents of the EWUAP project.

The consultant recommends for the EWUAP project to commence action by conducting training of trainers who shall be drawn from all of the Administrative Regions (provinces). In addition to the basic concepts, practices and themes of E*fficient Water Use for Agricultural Production*, the trainers require innovative skills of training of farmers, grass root technicians, experts and administrators. The skill transfer should also focus on techniques related to periodic skill gap analysis, performance monitoring and data base management. The EWUAP project has to establish a mechanism for monitoring the effectiveness of the prospective training program. In addition to classroom lectures, study tours could be arranged to the places indicated in section 11 and abroad.

The WH component, which includes various interventions in the rain fed agriculture, is associated with relatively large number of beneficiary population. Next populous component is the CMI. The Public Managed Irrigation schemes are in the process of privatization. In view of the potential impact, the consultant recommends the priority support area to be the WH schemes followed by the CMI schemes.

# I. REFERENCES

Abebe Y.D. and Geheb K., (eds). 2003. Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of Ethiopia's Wetlands. IUCN – EARO. Nairobi Kenya. http://www.iucn.org/themes/wetlands/pdf/Ethiopiawetlands.PDF.

Andrews, D.; Erasmus, L.; and Powell, R. 2005. Ethiopia: Scaling Up**.** Finance and Development: a quarterly Magazine of the IMF. September 2005, Volume 42, Number 3 http://www.imf.org/external/pubs/ft/fandd/2005/09/andrews.htm

Annen C. 2001. Promotion of Small-Scale Irrigation in Food-Insecure Weredas of Ethiopia. Submitted to IDA, World Bank

Awulachew S.B, Merrey, D.J, Kamara, A.B., Van Koppen, B. Penning de Vries, F., Boelee, E., Makombe, G. 2005. Experiences and Opportunities for Promoting Small Scale/Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia. Colombo, Sirilanka: IWMI. (Working Paper 98)

BCEOM - MoWR 1998. Abbay River Basin Integrated Development Master Plan; Main Report. Ethiopia

Brhane G. Yitayew Abebe, Fekadu Yohannes, Elias Zerfu, and Habtemariam Kassa. 2005. Integrated Agricultural Development Strategies in the ANRS: Lessons from the AMAREW project. Third EAF – EARO International Symposium on Development Studies in Ethiopia. June 17 – 18, 2005. Addis Ababa, Ethiopia. http://www.oired.vt.edu/amarew/pubs/EAF-EARO%20Sympaper%20AMAREW%20040205.pdf.

Carucci Volli 2000. Guidelines on Water Harvesting and Soil Conservation for Moisture Deficient Areas in Ethiopia: Manual for Trainers. WFP

COSAERT 2001. Preliminary Assessment on the Overall Impact of Dams. Mekelle, Ethiopia

Council of Ministers of Water Affairs of the Nile Basin States. 2001. Efficient Water Use for Agricultural Production: Project Document. NBI – SVP.

CSA, FDRE. 2005. Statistical Abstract. Addis Ababa, Ethiopia

EARO, AU, CIMMYT 2001. "Enhancing the contribution of Maize to food Security in Ethiopia": Proceedings of the Second National Maize Workshop of Ethiopia".

Ebrahim Mohamed, 2005. Extension Experience in Ethiopia. IPMS workshop on introduction to research and development for innovative extension systems, May 23 – 25, 2005. EARO, Addis Ababa, Ethiopia. http://www.ipms-ethiopia.org/docs/workshops-Meetings/Project_Launching%5CExtension%20Experiences%20in%20Ethiopia%20(Ebrahim%20Mohammed).pdf.

EPA 1997. Environmental Policy. FDRE. Addis Ababa, Ethiopia.

FAO, AGL 2005. Agricultural Water Use: Country Profile. http://www.fao.org/ag/agl/aglw/aquastat/countries/ethiopia/index.stm

Feldner K. et al 2004. Information Pack. Integrated Food Security Program, South Gonder. BOA-Amhara, GTZ

Foerch W. 2003. Case Study: The Agricultural System of the Konso in South-Western Ethiopia. FWU – WSM Publications, Siegen http://fwu.fb10.uni-siegen.de/bkd/deutsch/Publikation/Texte_FWU/volumen01/1-Wiebke-Konso-Pubs.pdf#search=%22konso%20conservation%20Ethiopia%20foerch%22

Gete Z., Menale Kassie, John Pender and Mahmud Yesuf 2006. Stakeholder Analysis for Sustainable Land Management (SLM) in Ethiopia: Assessment of Opportunities, Strategic Constraints, Information Needs, and Knowledge Gaps. EEPFE, IFPRI

Geremew, G., Asfaw Adugna, T., Taye, T., Tesfaye, B., Ketema, and H.S., Michael. 2004. Development of Sorghum Varieties and Hybrids for Dry Land Areas of Ethiopia. Uganda Journal of Agricultural Studies. 9:594 – 605. National Agricultural Organization. Uganda http://www.coard.co.uk/downloads/section09/papers/theme4/0594-0605-geremew.pdff

Girma T. Fentaw A. ND. The Nature and Properties of Salt Affected Soils in Middle Awash Valley of Ethiopia. http://www.iwmi.cgiar.org/assessment/files/word/publications/Workshoppapers/SALINITYFENTAWGIRMA1_ILRI.doc

HALCROW – EVDSA. 1989. Master Plan for the Development of Surface Water Resource in the Awash Basin. Addis Ababa, Ethiopia

Hatibu N, 2003. Rain Water Management: Strategies for Improving Water Availability and Productivity in Semi Arid and Arid Areas. IWMI; Sri Lanka
http://www.iwmi.cgiar.org/home/rainwater.htm

IFAD 2005 IFAD Loan and Grant 438 – ET Interim Evaluation Main Report.

IWMI, ADB, FAO, NEPAD, IFAD, WB 2004. Investment in Agricultural Water Management in Sub Saharan Africa: Diagnosis of Trends and Opportunities. ADB

Jabbar M.A., Peden D. G., Mohamed Saleem M.A., and Li Pun H (eds). 2000. Agro-ecosystems, natural resources management and human health related research in East Africa. Proceedings of an IDRC–ILRI international workshop held at ILRI, Addis Ababa, Ethiopia, 11–15 May 1998. ILRI (International Livestock Research Institute), Nairobi, Kenya. 254 pp.

Jinendradasa S. (ed) 2003. Issues of Water Management in Agriculture: Compilation of Essays. Comprehensive Assessment Secretariat. CGIAR.

Jutzi S C, Haque I, McIntire J and Stares J E S (eds). 1988. Management of Vertisols in sub-Saharan Africa. Proceedings of a conference held at ILCA, Addis Ababa, Ethiopia, 31 August-4 September 1987. ILCA, Addis Ababa.

Kidanemariam Jembere, 2005. (*Unpublished*) Report on Tigray Regional Water Partnership Launching Workshop: Promoting Integrated Water Resources Management (IWRM); Held on 2o$^{th}$ to 22$^{nd}$ December, 2005; Mekelle, Ethiopia; Ethiopia Country Water Partnership. Addis Ababa, Ethiopia.

King G. and Leul Kahsay 2005. Watershed Management Consultancy, Prioritization of Fast Track Projects: Selection of Project Areas. ENTRO, Addis Ababa, Ethiopia.

Lakew D. Carucci, V. Asrat W., and Yitayew Abebe (eds). 2005 Community Based Participatory Watershed Development: A Guideline. MoARD. Addis Ababa, Ethiopia

Landell Mills, 2004. Evaluation of the Water Harvesting Schemes Component of the EC Funded Programmes IFSP 1998 and IFSP 2000 in Tigray Regional State. EU SCR Framework Contract. Ethiopia

Leul K. 2004. Challenges and Research Needs in the Design of Community Based Irrigation System in Tigray. Ethiopia.
http://www.ilri.cgiar.org/data/livelihood/Proceedings/papers/9Leul.htm

Leul K. 1998. *(unpublished)* Financial Viability of Using Imported Low Pressure Gated Pipe Irrigation System in Tigray. COSAERT. Ethiopia.

Leul K. 2006. . *(unpublished)* Project Area Selection and Salient Features of Selected Sites. MoARD. Sustainable Land Management Project; Ethiopia

Mati B.M. 2005. Overview of Water and Soil Nutrient Management under Small Holder Rain fed Agriculture in East Africa. Working Paper 105. Colombo, Sri Lanka. IWMI

McCornick P.G., Kamara A.B. and Girma Tadesse, (eds). 2003. Integrated Water and Land Management Research and Capacity Building Practices for Ethiopia. Proceedings of a MOWR/EARO/IWMI/ILRI International Workshop held at ILRI, Addis Ababa, Ethiopia, 2 – 4 December 2002. IWMI, Colombo, Sri Lanka and ILRI, Nairobi, Kenya.

MCE, et al, 2002. Study on Research and Development Activities in the Water Sector. ESTC. Ethiopia

McHugh O.V., Collick A.S., Liu B.M., Debele B., Halmean J.E., Steenhuis T.S., Yitayew A., and Gete, Z. 2004. Can Integrated Watershed Management Bring Greater Food Security in Ethiopia? Cornell University, USA. AMAREW, Bahirdar, Ethiopia; ARARI, Bahirdar. Ethiopia.
http://www.bee.cornell.edu/swlab/SoilWaterWeb/publications/McHughIFAC.pdf

Metaferia Consulting Engineers, ECO – Consult 2002. Study on Research and Development Activities in the Water Sector. Ethiopian Science and Technology Commission. Addis Ababa, Ethiopia.

Ministry of Finance and Economic Development (MOFED), FDRE, 2002. Sustainable Development and Poverty Reduction Program. Addis Ababa, Ethiopia

Ministry of Information, FDRE 2001. Rural Development Policies, Strategies and Instruments., Addis Ababa, Ethiopia

Mintesinot B., Nata, T., Abiot L., Dagmawi, T. 2004. Community Based Irrigation Management in the Tekeze Basin: Performance evaluation of small scale Irrigation Schemes. MU, ILRI, EARO, IWMI. Ethiopia

Mintesinot B., Mohammed A., Atinkut M., and Mustefa M. 2005. Report on Community Based Irrigation Management in the Tekeze Basin: Performance Evaluation. MU, ILRI, EARO, IWMI. Ethiopia.

Mitiku Haile, Diress Tsegaye and Tegegne Teka (eds). 2004. Research and Development on Dryland Husbandry in Ethiopia. MU. OSSREA.

MOFED - FDRE, 2002. Sustainable Development and Poverty Reduction Program Addis Ababa, Ethiopia

MOARD 2005. Problems, Causes and Solution on the Implementation of Water Harvesting Works. (Report in Amharic) WH – SSI Department, MoARD, Ethiopia.

MOARD, 2005. Major Agro-Ecological Zones of Ethiopia. Forestry, Land Use, and Soil and Water Conservation Department. MOARD. Addis Ababa, Ethiopia.

MOARD, 2006. Vertisol Management: A guideline for Development Agents. Addis Ababa, Ethiopia.

MOWR, FDRE. 1999. Ethiopian Water Resources Management Policy. Addis Ababa, Ethiopia.

MOWR, FDRE. 2001. Water Sector Development Program. Addis Ababa, Ethiopia.

MOWR, FDRE. 2002. Ethiopian Water Resources Management Strategy. Addis Ababa, Ethiopia.

NBI, 2004. Efficient Water Use for Agricultural Production: Project Implementation Plan.

NBI – EWUAP 2006. Terms of Reference for National Consultant: Rapid Baseline Assessment.

NEDECO – DHV, 1998. Tekeze River Basin Integrated Development Master Plan Project; Main Report. MoWR. Ethiopia.

Ragab R. et al, (eds). 2002. Proceedings: Workshop on Crop Water Management for Food Production under Limited Water Supplies. 18th Congress on Irrigation and Drainage. ICID

Rami H. 2003. Ponds Filled with Challenges: Water Harvesting Experience in Amhara and Tigray. UN – OCHA. Ethiopia

Seme D. et al 2004. Millenium Development Goals Need Assessment: The Rural Development and Food Security Sector in Ethiopia (Draft). Addis Ababa Ethiopia.

Seyfu Ketema. 1997. Tef. *Eragrostis tef* (Zucc) Trotter. Promoting the Conservation and Use of Underutilized and Neglected Crops. Institute of Plant Genetics and Crop Plant Research Gateresleben/Inetrnational Plant Genetic Resources Institute, Rome, Italy

Tekalign Mamo, Abiye Astatke, K L Srivastava and Asgelil Dibabe (eds). 1993. Improved management of Vertisols for sustainable crop - livestock production in the Ethiopian highlands: Synthesis report 1986-92. Technical Committee of the Joint Vertisol Project, Addis Ababa, Ethiopia.

TECSULT - MOA. 2004. Woody Biomass Inventory and Strategic Planning Project: Terminal Report - Worksheets. Ethiopia

Tewodros M. Girma, A., Abder-Rahman, M. 2005. Effect of Reduced Tillage and Crop Residue Ground Cover on Yield and Water Use Efficiency of Sorghum Under Semi-Arid Condition of Ethiopia. World Journal of Agricultural Sciences 1 (2): 152 – 160, 2005. IDOSI Publications

TWRDB, REST, 2002. *(unpublished)* Manual on the Construction of Small Ponds in Tigray Region. Mekelle. Ethiopia.

WFP, 2004. Cost-Benefit Analysis and Impact Evaluation of Soil and Water Conservation and Forestry Measures. MERET. WFP. Addis Ababa, Ethiopia

WFP, 2005. *(unpublished)* Report on the cost-benefit analysis and impact evaluation of soil and water conservation and forestry measures (draft). MERET, Addis Ababa.

WFP - MERET project. 2002. Managing Environmental Resources to Enable Transitions to more Sustainable Livelihoods. Report of the WFP Appraisal Mission. Addis Ababa Ethiopia.

World Bank 2004. Project Appraisal Document: Efficient Water Use for Agricultural Production; NBI - SVP

Yaicob Likke. 2003. Irrigated crops Marketing Study. SPFS-in Ethiopia irrigation Component – Pilot Phase (GCSP/ETH/057/ITA). FAO

Zeleke G. and Yesuf M. 2006. (Unpublished) Proposal for a cost benefit Framework to support pro-SLM Decision Making in Ethiopia. Addis Ababa, Ethiopia

# ANNEXES

## ANNEX 1 Supporting Data to Section 1

**Annex 1-Table 1.1** Cropped Area and Yield of Selected Crops for 2000/2 – 2004/2005 in Ethiopia (under private peasant holdings only)

| Crop | 2002/2003 | | 2003/2004 | | 2004/2005 | | 3 years' Average Yield, Qt/ha |
|---|---|---|---|---|---|---|---|
| | Area, ha | Yield, Qt/ha | Area, ha | Yield, Qt/ha | Area, ha | Yield, Qt/ha | |
| Barley | 788692 | 8.75 | 920127 | 11.73 | 1095436 | 12.12 | 10.86 |
| Maize | 1191428 | 15.01 | 1367115 | 18.6 | 1392916 | 17.19 | 16.93 |
| Sorghum | 1071957 | 9.7 | 1283654 | 13.57 | 1253620 | 13.69 | 12.32 |
| Teff | 1931088 | 7.35 | 1989068 | 8.43 | 2135553 | 9.48 | 8.42 |
| Wheat | 997717 | 10.75 | 1098907 | 14.69 | 1398215 | 15.57 | 13.67 |

**Source:** CSA 2005

**Table Annex 1-Table 1.2** Crop Yield with and without Improved Technology Packages

| Year | Maize | | Wheat | | Teff | |
|---|---|---|---|---|---|---|
| | With Package | With Farmers' Traditional Practice | With Package | With Farmers' Traditional Practice | With Package | With Farmers' Traditional Practice |
| 1995/96 | 36.8 | 11.8 | 29 | 9.3 | 17.3 | 5.5 |
| 1996/97 | 51.7 | 17.6 | 25.9 | 10.6 | 15.3 | 6.5 |
| 1997/98 | 42 | 16.5 | 35 | 10.4 | 17 | 6.1 |
| 1998/99 | 51.8 | 15.5 | 24.6 | 10.8 | 12.8 | 5.5 |
| 1999/00 | 57.6 | 17.6 | 29.9 | 12.2 | 13.8 | 7.6 |
| 2000/01 | 40.5 | 16.5 | 25.5 | 12 | 16.5 | 8.3 |
| Mean | 46.7 | 15.9 | 28.3 | 10.9 | 15.4 | 6.8 |

**Source** (Seme et al 2004: adopted from Sasakawa Global 2000/Ethiopia Project: Activities and outputs – An Assessment, 1993 - 2001)

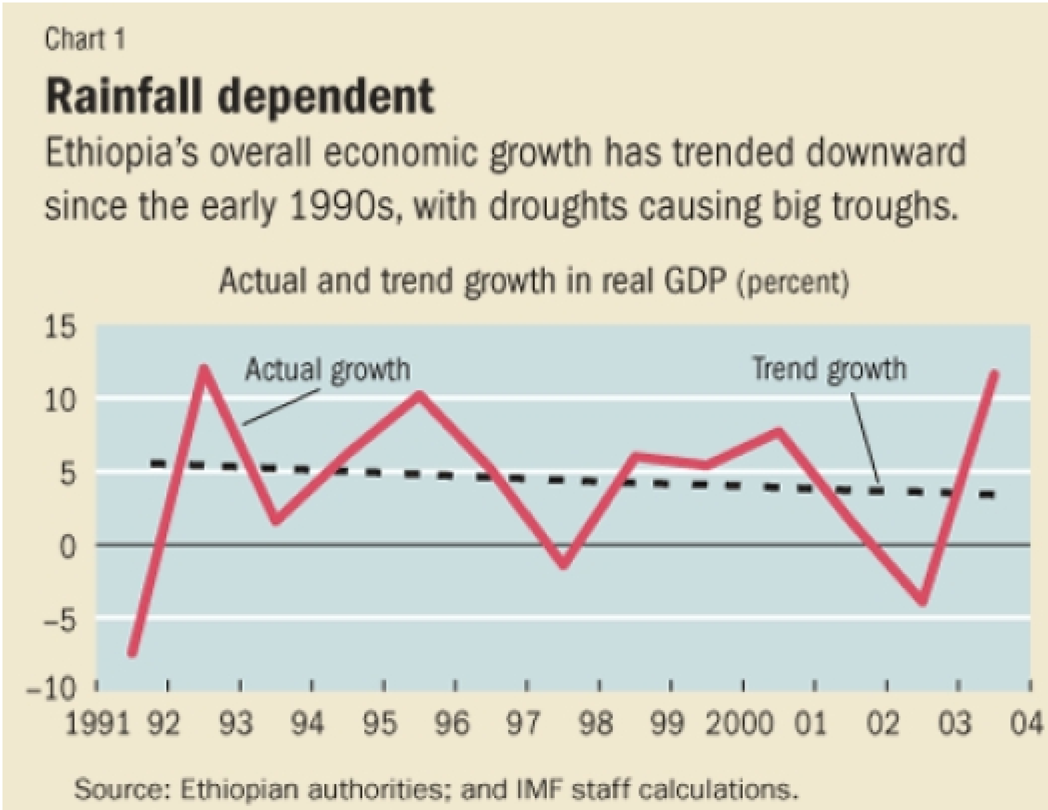
## ANNEX 2 Supporting Data to Section 2

**Annex 2-Table 2.1** Average Rain fed Crop Yield in Abbay Basin in 1994 – 1997, ton/ha

| Crop | Cropping Year | | |
|---|---|---|---|
| | 1994/95 | 1995/96 | 1996/97 |
| Cereals | | | |
| Teff | 0.67 | 0.715 | 0.773 |
| Barley | 0.803 | 0.897 | 0.911 |
| Wheat | 0.761 | 0.904 | 1.031 |
| Millet | 0.774 | 0.916 | 1.027 |
| Maize | 1.381 | 1.459 | 1.606 |
| Sorghum | 0.882 | 0.936 | 1.08 |
| Pulses | 0.516 | 0.574 | 0.639 |
| Oil Seeds | 0.324 | 0.373 | 0.403 |
| | | | |

**Source:** Abbay basin master plan study, 1999

**Annex 2-Figure 2.1** Rainfall Dependent GDP and its Growth Trend in Ethiopia




**Source:** Finance and Development: a quarterly Magazine of the IMF. September 2005, Volume 42, Number 3

**Annex 2-Table 2.2** Area under Irrigation in Mai Negus Irrigation Scheme at Different Years

Catchment Area = 12.62 km$^2$, Mean Annual Rainfall = 663 mm;

| Year | 1997/98 | 1998/99 | 1999/2000 | 2000/01 | 2001/02 |
|---|---|---|---|---|---|
| Irrigated Area (ha) | 88.1 | 91.3 | 101 | 73.72 | 109.3 |
| Irrigated Area (%) | 71.1 | 73.6 | 81.5 | 59.4 | 88.2 |

**Source:** (Behailu et al 2004 with primary data from BOANR of the Wereda)

**Annex 2-Photo 2.1** (a) and (b) Furrows/Ditches Constructed to Dispose Runoff from a Steep Slope Crop-Field in – Amhara

(a) (b)

**Source:** Geoff K. et al 2005, MOWR – ENTRO.

**Source:** Feldner et al 2004

**Annex 2-Table 2.3** Use of Dung and Crop Residue for Fuel and an Estimate of the Associated Loss

| Region | Residues as fuel (tons) | Dung as fuel (tons) | Loss of Nutrient N (tons) | P (tons) | Urea equivalent (tons) | DAP (P) equivalent (tons) | Loss of Cereal equivalent tons |
|---|---|---|---|---|---|---|---|
| **Amhara** | 2713327 | 4572689 | 42832 | 9344 | 93510 | 23069 | 214159 |
| **Oromia** | 1716473 | 1391768 | 17490 | 3289 | 38142 | 7990 | 87448 |
| **SNNP** | 280713 | 163946 | 2453 | 427 | 5346 | 1026 | 12264 |
| **Tigray** | 117028 | 663043 | 4829 | 1217 | 10555 | 3045 | 24143 |
| **Total of Four Regions** | **4827542** | **6791446** | **67603** | **14276** | **147554** | **35130** | **338015** |

**Source:** WBISPP 2004.

**Annex 2-Table 2.4** Effect of Different Soil Covers on Runoff and Soil Erosion at Holleta

| Treatment | Runoff, $m^3$/ha per Year | | Soil Erosion, t/ha per Year | |
|---|---|---|---|---|
| | 1986 | 1987 | 1986 | 1987 |
| **Bare Fallow Soil** | 785.6 | 612 | 32.6 | 22.9 |
| **Wheat Broadcast** | 684.5 | 624.2 | 28.1 | 12.3 |
| **Teff Broadcast** | 737.1 | 466.3 | 17.7 | 14.4 |
| **Grass Covered** | 143.9 | 106 | 0.9 | 0.3 |

**Source:** Jabbar et al (eds), 2000[29]

**Annex 2-Table 2.5** Actual and Designed Sedimentation Rate in some Reservoir Dams Built in Tigray

| Name of Reservoir | Location Lat/Lon | Year | | Catchment area $km^2$ | Total capacity $10^6M^3$ | Dead storage volume $10^6m^3$ | Designed sedimentation rate $m^3/km^3$,yr | Actual sedimentation rate $m^3/km^3$,yr |
|---|---|---|---|---|---|---|---|---|
| | | Constructed | When dead storage filled up | | | | | |
| Gereb Mihize | $13^{0}14^{1}16^{11}$ $39^{0}27^{1}00^{11}$ | 1998 | 2002 | 17.2 | 1.2 | 0.325 | 950 | 4724 |
| Adi Kenafiz | $13^{0}14^{1}40^{11}$ $39^{0}22^{1}30^{11}$ | 1998 | 2001 | 13 | 0.67 | 0.067 | 1200 | 1719 |
| Mai Gassa | $13^{0}14^{1}16^{11}$ $39^{0}27^{1}01^{11}$ | 1997 | 2001 | 9 | 1.3 | 0.153 | 970 | 4270 |
| Gra Shetu | $13^{0}12^{1}10^{11}$ $39^{0}30^{1}20^{11}$ | 1998 | 2001 | 2.88 | 1.42 | 0.028 | 1000 | 3291 |

**Data Source:** TBWRD

[29] Adapted from: Asrat Abebe. 1992. Assessment of runoff and soil losses under different cover crops and slope length. In: Natural resource management for conservation and development. Proceedings of the Second Natural Resources Conference, Addis Ababa, Ethiopia, 10–13 May 1990. pp. 50–56.

## ANNEX 3 Supporting Data to Section 3

**Annex 3-Table 3.1** Crop Yield under PADETES and Conventional Farmers Practices 1995 – 2001, and Number of Farmers involved in the Food Crop Extension

| Year | Maize, ton/ha | | Wheat, ton/ha | | Sorghum, ton/ha | | Teff, ton/ha | | No. of Farmers involved 000 |
|---|---|---|---|---|---|---|---|---|---|
| | PADETES | Conventional | PADETES | Conventional | PADETES | Conventional | PADETES | Conventional | |
| 1995 | 3.7 | 1.0 | 2.9 | 0.9 | 2.7 | 0.8 | 1.3 | 1.0 | 32 |
| 1996 | 5.4 | 1.7 | 2.8 | 1.2 | 4.5 | 1.4 | 1.5 | 0.8 | 350 |
| 1997 | 3.7 | 1.7 | 3.5 | 1.3 | 1.9 | 1.0 | 1.7 | 0.9 | 584 |
| 1998 | 5.2 | 1.6 | 2.5 | 1.4 | 3.0 | 1.1 | 1.3 | 0.7 | 2122 |
| 1999 | 5.8 | 1.8 | 3.0 | 1.2 | 1.9 | 1.1 | 1.4 | 0.8 | 2804 |
| 2000 | 4.1 | 1.7 | 2.6 | 1.2 | 2.1 | 1.0 | 1.7 | 0.8 | 2987 |
| 2001 | 3.7 | 1.1 | 2.4 | 1.1 | 2.1 | 0.8 | 1.3 | 0.6 | 2616 |
| | | | | | | | | | |

**Source:** Ebrahim 2005

**Annex 3-Table 3.2** Effects of Modified Plow on Yield Compared with Traditional Plow

| Crop | Plowing Frequency | Yield Increment Attributed to Modified Plow Compared with Traditional Plow, % | | | |
|---|---|---|---|---|---|
| | | Plot number | | | |
| | | 1 | 2 | 3 | 4 |
| Wheat | 3 | 25.7 | 42 | 32.4 | 25.5 |
| Teff | 1 | 9 | 10.8 | | |
| | 2 | 39.2 | 35.9 | | |

**Data Source:** Feldner et al 2004

**Annex 3-hoto 3.1**Tenkara Kend (modified Ox drawn Plow) and Indigenous Plow

Indigenous Plow

Tenkara Kend (Cost: Birr 160 – 175)
Working Life: 10 – 15 Years

**Source:** Feldner et al 2004

**Annex 3-Table 3.3** Effect of Increasing Tillage Depth on Plant Biomass and Grain Yield

| Treatment | Depth of plow cm | Additional cut below plow depth, cm | Above Ground Biomass Ton/ha | Root Mass per Plant gm | Plant Density Plants/m$^2$ | Grain Yield Ton/ha |
|---|---|---|---|---|---|---|
| Sub cultivator [30] | 8 - 15 | 6 – 12 | 7.98 | 10.8 | 8.4 | 1.90 |
| Tied Ridges[31] | 8 - 15 | -- | 7.01 | 11.9 | 6.8 | 1.43 |
| Open Ridges | 8 - 15 | -- | 7.82 | 10.2 | 8.5 | 1.38 |
| Traditional Plow | 8 - 15 | -- | 6.49 | 8.3 | 7.8 | 1.34 |

**Source:** McHugh et al 2004

**Annex 3-Table 3.4** Effect of Tillage and Mulch Rate Interaction on Sorghum Grain Yield (kg/ha) at Melkassa in 2003

| Mulch rate (mg/ha) | Tillage Systems | | | |
|---|---|---|---|---|
| | Conventional Tillage | Zero Tillage | Tied Ridging, 35 cm high; 75 cm spacing | Mean |
| 0 | 2404 | 2156 | 4190 | 2916 |

[30] The sub cultivator is similar to the traditional ox drawn plow but with a blade extension which cuts the soil an additional 6 – 12 cm without turning the soil.

[31] The plots were first plowed with the traditional plow. Then, the week before sowing, the open and tied ridges were plowed along the contour using ox-drawn ridger. The ridges were50 cm apart with amplitude of 10 – 13 cm and an average ridge width of 27cm.

| | | | | |
|---|---|---|---|---|
| 3 | 4076 | 3141 | 3558 | 3591 |
| 6 | 4688 | 3867 | 3859 | 4138 |
| Mean | 3722 | 3054 | 3869 | |

**Source:** Tewodros M. et al 2005.

**Annex 3-Table 3.5** Effect of Tie Ridges on Crop Yield under Semi Arid Regions of Ethiopia

| Crop | Treatment | Grain Yield, ton/ha | |
|---|---|---|---|
| | | Kobo | Melkassa |
| Sorghum | Flat Planting (farmers Practice) | 1.6 | 0.8 |
| | Tied Ridges (Planting in Furrow) | 2.9 | 3.0 |
| Mung Bean | Flat Planting (farmers Practice) | 0.4 | |
| | Tied Ridges (Planting in Furrow) | 0.7 | |
| Maize | Flat Planting (farmers Practice) | 1.2 | |
| | Tied Ridges (Planting in Furrow) | 2.7 | |

**Note:** Ridge height = 35 cm; Ridge Spacing 80 cm for mung bean; 75 cm for sorghum and maize; Ridges tied at 6m intervals.

**Source:** Mati B.M, 2005[32]

**Annex 3-Table 3.6** Effect of Bed Height of BBF on Grain Yield of Wheat at Ginchi and Akaki in 1991

| Location | Treatment | Bed Height cm | Yield Kg/ha | % yield increase over Control |
|---|---|---|---|---|
| Ginchi | Flat (control) | 0 | 835 | |
| | Normal BBF | 13 | 979 | 17 |
| | Raised BBF | 26 | 1221 | 46 |
| | | | | |
| Akaki | Flat (control) | 0 | 960 | |
| | Normal BBF | 13 | 1286 | 34 |
| | Raised BBF | 26 | 1481 | 54 |

**Source:** (Tekalign et al, 1993)

**Annex 3-Table 3.7** Effect of BBF on Runoff and Soil Loss from Wheat Cropped Plots at 2.7% Slope at Hidi in 1987

[32] Adopted from "Kidane G; Rezene F. 1989. Dryland Research Priorities to Increase Crop Productivity. In *Proceedings of the* 21[st] NCIC Workshop, April 10 – 12, Addis Ababa, Ethiopia; 57 - 64

| Treatment | Rainfall (July – Sept) mm | Runoff, mm | Soil Loss, ton/ha |
|---|---|---|---|
| Flat | 453 | 66 | 3.72 |
| BBF laid at 2.7% gradient | 453 | 124 | 7.0 |

**Source:** (Tekalign et al, 1993)

**Annex 3-Table 3.8** Effect of Improved Vertisol Management on Wheat Yield under Farmers Condition

| Region | Wereda | Number of Participating Farmers | Wheat Yield Ton/ha | | Percent Increase % |
|---|---|---|---|---|---|
| | | | Farmers' Practice | Improved Practice | |
| Oromia | Becho | 152 | 0.5 | 2.3 | 78 |
| | Dendi | 163 | 0.5 | 2.5 | 80 |
| | Alemgena | 120 | 0.9 | 2.4 | 62 |
| | Ambo | | 0.5 | 1.5 | 67 |
| | Alu | 60 | 0.8 | 2.2 | 64 |
| | Yayagulele | 155 | 0.5 | 2.7 | 81 |
| | Bereh Aleltu | 40 | 0.6 | 2.9 | 79 |
| | Akaki | 55 | 0.8 | 2.7 | 70 |
| | Chefe Donsa | 56 | 0.8 | 3.4 | 76 |
| Amhara | Enewari | 323 | 1.2 | 3.3 | 64 |
| | Dejen | 20 | 0.7 | 1.4 | 50 |
| | Enemai | 30 | 1.0 | 3.0 | 67 |
| | Enebse | 35 | 1.0 | 3.1 | 68 |

**Source:** MOARD 2006, (Adapted from Sasakawa Global 2000)

**Annex 3-Table 3.9** Improved Maize Varieties Released in Ethiopia

| Variety | Year Released | Altitude, meter | Maturity, days | Yield, ton/ha At Research Station | Yield, ton/ha On-Farm |
|---|---|---|---|---|---|
| (a) Highland | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| BH660 | 1993 | 1600-2200 | 160 | 9-12 | 6-8 |
| Kuleni | 1995 | | 150 | 6-7 | 4-4.5 |
| Rare - 1 | 1997 | | 163 | 6-8 | 3.8-4.2 |
| Other maize varieties evaluated in 2000 are also documented. | | | | | |
| (b) Mid and Low Altitude | | | | | |
| BH660 | 1993 | 1600-2200 | 160 | 9-12 | 6-8 |
| Kuleni | 1995 | 1700-2200 | 150 | 6-7 | 4-4.5 |
| A-511 | 1974 | 500-1800 | 150 | 5-6 | 3-4 |
| Gibe-Comp-1 | 2000 | 1000-1700 | 145 | 6-7 | 4-4.5 |
| etc | | | | | |
| (c) Drought Stressed Areas | | | | | |
| Katumani | As of 1993 | Drought Tolerant | 110 | 3.1 | |
| Melkasa-1 | | | 85 | 4.2 | |
| A-511 | | | 135 | | |
| etc | | | | 5.6 | |

**Source:** "Enhancing the contribution of Maize to food Security in Ethiopia": Proceedings of the Second National Maize Workshop of Ethiopia". 2001. CIMMYT, EARO, Alemaya University.

## *ANNEX 5 Supporting Data to Section 5*

**Annex 5-Table 5.1**Types of SWC Activities Being Implemented in Ethiopia and their Work Norms

| No. | Activity | Unit | Norms |
|---|---|---|---|
| 1 | Soil bund | PD/km | 150PD/km |
| 2 | Stone bund | PD/km | 250PD/km |
| 3 | Fanya-juu | PD/km | 200PD/km |
| 4 | Planting on bund | PD/km | 16PD/km |
| 5 | Hillside terracing | PD/k | 250PD/km |
| 6 | Cut-off drain construction | $M^3$/PD | 0.70 $M^3$/PD |
| 7 | Grassed waterway construction | $M^3$/PD | 1.0 $M^3$/PD |
| 8 | Bench terrace construction | PD/km | 500PD/km |
| 9 | Stone check-dam construction | $M^3$/PD | 0.5 $M^3$/PD |
| 10 | Stone check-dam maintenance | $M^3$/PD | 1 $M^3$/PD |
| 11 | Seedling production | PD/1000 seedling | 15PD/1000 |
| 12 | Pitting | PD/pits | 1PD/15 Pits |
| 13 | Micro-basin construction | PD/micro-basins | 1PD/5MB |
| 14 | Seed collection (*) | PD/kg | 20PD/kg |
| 15 | Seedling planting | PD/Plants | 1PD/50 plants |
| 16 | Site guarding | PD/Ha./year | 4PD/ha/year |
| 17 | Small farm dam construction | $M^3$/PD | 0.4 $M^3$/PD |
| 18 | Pond construction | $M^3$/PD | 0.5$M^3$/PD |
| 19 | Farm road construction | PD/km | 3000PD/km |
| 20 | Road maintenance/construction on <5% slope | PD/Km | 500PD/km |
| 21 | Spring development | No | 1700 PD/spring |
| 22 | Stream diversion weir | No | 3000 PD/weir |
| 23 | Grass and legume seed production (multiplication center) | No | 700 PD/ha/year |
| 24 | Bund maintenance | - | Self-help |
| 25 | Other structures/assets maintenance | - | Self-help |

(*) Seed collection has a different specific norm (60 PD/kg) for *Grevillea robusta* seeds only

**Source:** Lakew D. et al 2005

**Annex 5-Table 5.2:** Comparative Costs for WH Structures

| | Type of WH Structure | Type Dimension | Capacity, $m^3$ | Cost, Birr | Unit cost Birr/$m^3$ Water |
|---|---|---|---|---|---|
| **1** | Dugout, Trapezoid | 12x12 clay lined | 190 | 5753 | 30.3 |
| **2** | Dugout, Trapezoid | 12x12 Plastic lined | 190 | 6131 | 32.3 |
| **3** | Dugout, Trapezoid | 10x10 clay lined | 130 | 4227 | 32.5 |
| **4** | Dugout, Trapezoid | 10x10 Plastic lined | 130 | 4542 | 34.9 |
| **5** | Dugout, Trapezoid | 8x8 clay lined | 80 | 2892 | 36.1 |
| **6** | Dugout, Trapezoid | 8x8 Plastic lined | 80 | 3126 | 39.1 |
| **7** | Hemispherical tank | 1 Cement : 6Termite soil for the floor & walls; Roof = locally available material | 60 | 2790 | 46.5 |
| **8** | Hemispherical tank | 1 Cement : 3 Sand soil for the floor & walls; Roof = locally available material | 60 | 3056 | 50.9 |
| **9** | Spherical Tank | Cement & soil blocks 1:4; Cement & sand mortar 1:3 | 15 | 1946 | 129.7 |
| **10** | Bottled Shaped Tank | Concrete base 1:3:4; rest is cement & sand 1:3 | 30 | 2059 | 68.6 |
| **11** | Dome Shaped Tank | Concrete floor & roof 1:3:4; rest is cement & sand 1:3 | 60 | 4607 | 76.8 |
| **12** | Dome Shaped Tank | Wall is cement &sand 1:3; Roof – bricks. Concrete floor 1:3:4 | 60 | 4966 | 82.8 |

**Source:** EU 2004

**Annex 5-Table 5.3** WH Structures and irrigated Land Implemented in 2003 – 2004

| Type of WH structure | Average Capacity per structure $M^3$ | Quantity and Irrigated Area (ha) per Regions/Provinces | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Oromia | | SNNP | | Amhara | | Tigray | |
| | | No | Ha | No | Ha | No | Ha[33] | No | Ha |
| Dome shaped | 60 | | | 104 | NA | 1045 | NA | - | |
| Hemispherical Pond (Lined) | 60 | 509 | NA | | | 14466 | NA | - | |
| Dugout Unlined | 57 - 182 | 122199 | NA | 54395[34] | | 6372 | NA | 70892[35] | NA |
| Dugout Lined | 57 - 182 | 13386[36] | NA | 24238 | 424 | 6789 | NA | | |
| Community Ponds (for irrig & Livestock | 5000 | | NA | 8943 | 41.5 | 19354 | NA | 155 | NA |

[33] Sample survey from Gubalfto and Bati Weredas indicate that 12.9% and 9.3% of the WH structures were not operational in 2003 – 2004. 60 hand-dug wells in Gubalfto Wereda enabled to irrigate 12.4 ha and water supply for domestic and a total of 600 livestock.
[34] 54395 dugouts (69%) were not able to store water as they were not provided with either plastic or earth lining.
[35] 15,432 ponds were not operational.
[36] 30200 (22.2%) ponds were not operational

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| water supply) | | | | | | | | | |
| Spring | | | | 15952 | 1026 | | NA | | |
| Stream | | | | | | | NA | | |
| Hand dug well | 6 – 15 deep | 61039 | 128 | 57899 | 650 | 188818 | NA | 20,000 | NA |
| In-Situ Moisture Conservation | | | | NA | NA | | | | |

**Source:** MoARD 2005.

**Annex 5-Table 5.4** Conveyance and Application Efficiencies in Three CMI Schemes in Tekeze basin

| Parameter | Community Managed Irrigation Scheme; % | | | Remark |
|---|---|---|---|---|
| | Meila | Haiba | Mai Negus | |
| Conveyance Efficiency | 74.8 | 53.2 | 58.26 | a |
| Application Efficiency (when rooting depth was at about 20 cm) | 72.84 | 64.7 | 85.4 | b |
| | | | | |
| Irrigation Efficiency | 54.48 | 34.42 | 49.75 | c |

**Source for a and b:** MU, ILRI, EARO 2005;

**Source c:** = a x b

**Annex 5-Photo 5.1** Conveyance Loss in Haiba CMI, Tekeze Basin

**Source:** MU, ILRI, EARO 2005

**Annex 5-Table 5.5** Estimates of Irrigation Efficiencies for Major Farms in the Awash River Basin

| Farm Name | Major Crop Grown | Overall Irrigation Efficiency, % |
|---|---|---|
| Wonji – Shewa | Sugar cane | 50 |
| Nura Era Complex | Horticulture | 30 |
| Metahara and Abadir | Sugar cane | 50 – 55 |
| Amibara | Cotton | 50 |
| Angelele Pump Scheme | Cotton | 35 – 40 |
| Gewane | Cotton | 35 |
| Dubti, Dit Bahri | Cotton | 35 – 40 |
| Assaita | Cotton | 30 |
| Small Settlment Farms | | 30 - 35 |

**Source:** Halcrow 1989

# ***ANNEX 6 Supporting Data to Section 6***

**Annex 6-Photo 6.1** Short Furrow Length in Tigray - Ethiopia

**Source:** TBOWRD 2003.

**Annex 6-Photo 6.2** Wild Aloe in Raya Azebo Wereda

**Annex 6-Photo 6.3** Sisal as Live Fence in Kondaltiti Wereda

## ANNEX 11 Supporting Data to Section 11

**Annex 11-Photo 11.1** Bishan Behe Spate Irrigation

**Source:** Lakew D., 1995

**Photo Annex 11-Photo 11.2** Terraced Landscape in Konso Area

Source: www.ad.jyu.fi/.../ethiopia/photos-konso.html

## Persons Contacted

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END