INVENTORY, SUITABILITY ASSESSMENT, AND UPSCALING OF BEST AGRICULTURAL WATER MANAGEMENT PRACTICES

Makonnen Loulseged[1], Seleshi Bekele Awulachew[2], Gayathree Jayasinghe[3], Fitsum Hagos[4] and Teklu Erkossa[5]

[1]*Water Resources Expert*, [2]*Senior Researcher*,[3]*Biometrician*, [4]*Economist*, [5]*Agricultural/Irrigation Engineer, International Water Management Institute (IWMI), East Africa and Nile Basin Office, Addis Ababa, Ethiopia*
m.loulseged@cgiar.org

Abstract

It is the belief of many analysts that agrarian countries like Ethiopia that depend on rain-fed agriculture are significantly vulnerable to rainfall variability, the risk which tends to aggravate with global climate change. Consequently, it is believed that future increases in food supplies and economic prosperity depend heavily on effective agricultural water management. It is with this in mind that the use of low-cost technologies for rainwater and runoff control, storage, water lifting, conveyance and application have become more widespread in Ethiopia since the recent drought of 2002/2003. A range of technologies are currently used with varying levels of impacts. This paper outlines an inventory, characterization, suitability and upscaling aspects of Agricultural Water Management Technologies (AWMT) in Ethiopia. Particular characteristics of each of the technologies, their suitability for a given environment, and the necessary conditions for their successful adoption and scaling up are identified. Furthermore, a variety of combinations of technologies used for control or storage, lifting, conveyance and application of rainwater are documented. Suitability of a technology in a particular environment depends on many factors, such as, the nature of technical complexity, the existing institutional and individual capacity to implement, the costs and benefits, etc. Technical considerations include implementation (set up), operation and maintenance, affordability and environmental impact. The results of a ranking exercise of the technical complexity of a given technology are presented. Concerns related to waterborne and water-related diseases due to stagnation, water quality and possibility of mosquito breeding are discussed.

Households in some parts of Ethiopia, who have practiced improved agricultural water management suitable to their local conditions, have managed to diversify their incomes through beekeeping, livestock, intercropping cash crops with food crops and setting up shops, hotels and flour mills in the nearby towns or villages. Therefore, AWMT at smallholder level meet the intended purpose, provided that they are suitable and adaptable to the local circumstances. The question is which of the technologies are suitable to which area under what socioeconomic conditions?

Introduction

Ethiopia covers a land area of 1.13 million km^2, with a population of 77 million at 2007 estimate. The physiographic is characterized by complex highland mountains and plateaus. The agricultural potential is largely unexploited; with less than 40% of the arable land currently under cultivation. Rainfall is generally greatest (around 2200 mm per annum) in the southwest highlands and decreases to around 600 mm per annum in parts of the northeastern highlands. Much of the rainfall in the country occurs between June and September only in the southern and eastern highlands, there are pronounced bimodal rains with the first peak in April and the second in September. Rainfall variability generally increases as rainfall itself decreases and is thus generally greatest in the lower rainfall areas of the north and northeast highlands. The mean daily temperature in the highlands during the growing season (May to December) is 21.3^{o}C, and drops by 0.6^{o}C for each 100 meters increase in altitude (Goebel, 1983).

The cultivable land is about 13.2 million ha, or 12% of the total land area (FAO, 1998). But agricultural productivity remains very low partly due to limited access to agricultural technologies, limited possibility to diversify agricultural production, underdeveloped infrastructure, and weak or sometimes lack of access to agricultural markets and to technological innovations (S.B Awlachew et al., 2005). As a consequence the rural dwellers in the country are among the most vulnerable to poverty as they entirely depend on agriculture for their livelihood. The agriculture sector is highly dependant on rainfall, thus the amount and temporal distribution of rainfall and other climatic factors during the growing season have an important influence on crop yields. When rainfall variability increased across the country, average food production per capita has also declined in the past years, and the country has become increasingly dependent on imported food. Presentation made on Impact of Irrigation on Poverty and Environment (IIPE) Symposium (S.B. Awlachew, 2007) confirms that the performance of Ethiopian economy is directly linked to rainfall variability (Figure 1). It is estimated that in Ethiopia, one drought event in 12 years lowers GDP by 7 to 10% and increases poverty by 12 to 14 percent. This calls for use of effective and efficient agricultural water management technologies to mitigate its negative impacts. At the same time, the country is endowed with surface and ground water that can be used for boosting agricultural production sustainable.

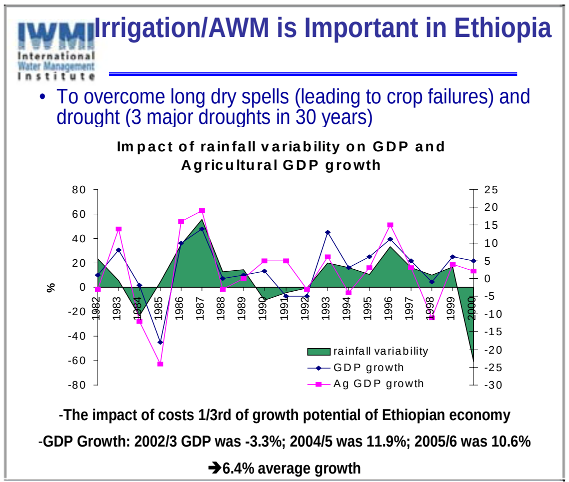

Figure 1: IIPE Symposium presentation, S.B. Awlachew (2007)

Water resources and AWMT

The country is faced with a rapidly growing population and an agricultural production which in most years, falls short of the food requirements mainly because of rainfall variability. The total mean annual flow from all the river basins is estimated at 123 BMC. Only about 200,000 ha has been developed using irrigation and yet more land has to come under irrigation to feed the fast growing population and combat the effect of drought. Different types of irrigation have been used in different parts country, ranging from small scale traditional methods to large-scale commercial farms.
There are twelve river basins twenty lake bodies, four crater lakes and over twelve major swamps or wetlands. Irrigation in Ethiopia is classified as large with a command area greater than 3000 ha, medium with a command are between 200 and 3000 ha; small scale with a command area less than 200 ha. The small scale irrigation (SSI) schemes are managed by the community. The estimated 48,000 ha is under modern small scale irrigation (S.B. Awulachew et.al, 2005) and the traditional irrigation estimate is about 13,820 ha. However, if it were not because of lack of proper inventory, the total area irrigated using modern and traditional methods exceeds this amount.

Recently, rainwater harvesting and use for agricultural production has become common to many areas. Harvesting runoff during the rainy season can supplement irrigation development and fill the gap during the drought season in rain fed agriculture. Massive program was planned by the government during the period 2001 to 2005 and implemented by individual households. Farmers have continued adopting these technologies and have continued benefiting in areas where it has become successful. The use and adoption level of the different types of technologies differs from place to place. However, water management efficiency and production level of agricultural outputs has remained a question in many of the places even in areas where there is successful adoption.

Objectives

The overall objective of the AWMT project is to contribute to improving the lives of rural poor through improved and sustainable agricultural productivity and generation of incomes for smallholder farmers in Ethiopia. Specifically, this study aims at assessing suitability of AWMT and identification of promising technologies for scaling up.

Methodology

The method of collecting data and information included literature review from both local and international sources, key informants interviews and discussions at all levels including federal, regional and in some instances at zonal and woreda levels. In addition, a questionnaire was designed and distributed to relevant experts in various institutions (GO, NGO, UN agencies, private, etc) to capture diversified information on agricultural water management practices, ranking of technologies and suitability including the constraints that exist (**Annex 1**). Where conditions favor site observations were made and discussion with individual farmers were also held.

Limitations

This study was based on a one time field visit to regional capital of Amhara, SNNP, Tigray and Eastern and Western Hararghe zones of Oromia regional state where most agricultural water management technologies are practiced. Few promising technologies were also visited during the field trip. In view of the broad scope of the study, which covers the entire country and the diversity of technologies, the time allocated to the project was not adequate. In addition, farmer's involvement in the study was not adequate. However, the information through the various tools is believed adequate to present the general overview of agricultural water management technologies in Ethiopia.

Depending on the topography, agro-climatic conditions and the farming systems, different types of AWMT are used in different parts of Ethiopia. There has been no exhaustive inventory of modern as well as traditional AWMT in Ethiopia. Therefore, the first part of this study "identification and characterization of AWMT" is the first of its kind in documenting a wide range technologies all together in one. More than 50 agricultural water management technologies practiced in Ethiopia were identified through the inventories. The information made available through this study can serve as a reference for further investigations. Annex 2 provides summary of these technologies, their advantages and constraints in brief.

Rainwater harvesting for crop production, if successfully implemented within a social and hydrological catchment, will have many interacting implications on biophysical, economic, and ecological systems, suggesting that a systems approach needs to be considered when promoting Rain Water Harvesting (RWH) (Rockstrom, 2000). Water harvesting structures built without consideration of the whole catchment have faced serious problems like siltation, water shortage, conflict of interest, etc. The suitability of AWMT depends very much on the specific environment and local conditions of a particular area. Some of the conditions broadly include agro-ecology, infrastructure, socioeconomic conditions (market, cultural, etc).

While altitude, temperature and rainfall determine the range of cropping possibilities, the actual patterns of cropping that predominate are determined primarily by the lengths of growing periods and by socio-economic considerations. Other physical conditions such as soils are also important in influencing potential for plant growth. Crop management practices such as cropping systems, fertilizer, and weed and pest control also determine the efficiency of agricultural water use. Intercropping cash crops with food crops is practiced in some areas to maximize the production from a limited farm size of a water harvesting structure and may ultimately contribute to the success of the technology. In consideration of the above, the high and low potential cereal zones and high potential perennial crop zones have been classified by Ethiopian Highland Reclamation Study as shown in Annex 3.

One of the main constraints in the scaling up of any conservation measures is non ownership of asset by farmers. Livelihood is a pressing day to day question to farmers and as a result farmers often fail to focus on long term objectives but rather they need early return to any investment. As a result, interventions with long term gestation period are not generally favored by farmers. The dwindling land holding size of farmers where they can not afford to allocate portion of their plot to be used for conservation structures is also another bottleneck to scaling up of agricultural water management technologies.

Technology suits in practice

There are different combinations of technologies that are used from the source up to delivery of water to crops. Affordability, experience, availability, lack of awareness is among the factors that influence these combinations. The commonly adapted combination of agricultural water management suits are shown in Annex 4. However, the choice, adoption, suitability and success of AWM technologies were not clear. Out of the results of the 2006 symposium and other sources of information, it has become clear that some technologies are working very well in some parts of the country and fail in others. **Annex 5** presents the location of these technologies where they are widely adopted and practiced.

Conditions of suitability for agricultural water management technologies

The appropriateness micro-catchments to specific agro-ecological conditions is crucial to the success of technological interventions. In drought-prone semi-arid areas, the introduction of rainwater harvesting is generally successeful, although fluctuation in the amount of rainfall remains to be a major constraint. For example, half moon is implemented in areas receiving rainfall less than 500 mm. It is suitable in areas with sandy and sandy loamy soils affected by low fertility levels and thin surface crusts that inhibit infiltration and increase runoff. On the other hand, Fanya Juu is well adapted in areas where the rainfall ranges between 500 to 1400mm. It is widely practiced in Dega, Woina Dega agro-climatic zones, dominated by heavy soils and where erosion problem is critical.

The suitability of technologies depends also on the specific site conditions, such as slope, soil depth, cropping pattern, erosion level, etc. According to L. Desta, et al., 2005, the measures listed from **Annex 6 to 9** are broad indications of suitability of soil and water conservation interventions based on agro-climatic conditions and land use. For example in cultivated land and homestead areas, measures like soil bunds, stone bund, fanya juu, BBF, etc. are appropriate. Flood control and drainage measures like vegetative or stone paved waterways are suitable for grazing lands. Stone faced soil bunds and cut off drains are more suitable for forest areas with steep slopes where as level bunds are better **s**uited in gently sloping and moderately sloping areas. In general, conservation technologies are varied and their appropriateness is agro-ecology based and purpose oriented.

Open ponds are suitable where unskilled labor is abundantly available, evaporation loss is relatively low**,** when efficient water conveyance and application technologies are used, when there is limited capital to invest but, unsuitable where there is severe shortage of land and where favorable conditions exist for malaria proliferation. Underground cisterns are suitable where skilled labor is available, evaporation and seepage loss is relatively high, there is severe water scarcity**,** when higher water quality is required and in areas of free grazing.

In situ technologies are most suited to conserve soil, water and increase vegetation cover and when there is a need to increase ground water recharge for shallow well exploitation. Shallow ground water and spring development are suitable when good quality and dependable source of water is required. Shallow well is less functional in loose soils due to likely construction difficulties.
Practitioners agree that if technologies are to become successful series of chain of measures are required. Production of crops have to be linked to cooperatives, this in turn linked to processing plants, again linked to market, etc. A system approach would involve different biophysical disciplines within a watershed and linkages between the agro ecological system and rural society, and between production and marketing, among others (Stephen N. Ngigi, et. al 2003).
Rainwater harvesting techniques can be applicable in all agro climatic zones. However, it is more suitable in arid and semi arid areas. These are areas of average annual rainfall <800mm (rarely exceeding 800mm). Rain may not come on time and in such environment, rain fed crop production usually needs to be supplemented with rainwater harvesting.

According to Oweis T., D. Prinz and A. Hachum. 2001, generally water harvesting is advantageous in the following circumstances:

- In dry environment, where low and poorly distributed rainfall normally makes agriculture production impossible
- In rainfed areas, where crops can be produced but with low yields and a high risk of failure. Here, water harvesting systems can provide enough water to supplement rainfall and increase and stabilize production.
- In areas where water supply for domestic and animal production is not sufficient
- In arid areas suffering from desertification, where the potential for production is diminishing, due to lack of proper management. Providing water to these lands through water harvesting can improve the vegetative cover and can help to halt environmental degradation.

In country experiences and lessons drawn from other countries indicate that adoption of new technology becomes more effective if supported by applied research and demonstration sites.

Furthermore, a guideline shown in Annex 7 can be used for selecting water harvesting techniques depending on the soil type, topography, land cover and other socio-economic considerations (Oweis, T., D. Prinz and A. Hachum, 2001).

The performance of technologies in terms of implementation, operation and maintenance, affordability, gender sensitivity, environmental impact, etc., has also been assessed through a questionnaire. Suitability depends on the nature of technical complexity, the existing institutional and individual capacity, the investment capital and operation and maintenance cost, and benefit. Therefore an elaborated suitability criteria has been developed, and has been integrated into the questionnaire to get experts feed back. The summary of the performance of technologies as per the feed back obtained from four regions has been presented in Annex 10.

Promising technologies

Earlier inventories carried out by different institutions for different purposes provide indicative information on the type of technologies used and the level of their utilization. Tables 1 below indicate the type of technologies and extent of their adoptability and usage in three regions. In SNNPR, based on the available information almost all small scale irrigation development comes from river diversion.

Table 4: Commonly practiced AWM technologies in Amhara Region

Technologies	Amhara Region coverage (%)	Oromia Region irrigation coverage by water source (%)	Tigray Region coverage (%)
River diversion	95	69	75
Micro dam	0.1		6
Pump	1.1		
Hand dug shallow well	3.5		12.7
Deep wells			0.2
Pond	0.3	2	6.03
Spring development		21	
Spate irrigation			0.07
Lake		8	
Total	100	100	100
Source BoWR, Amhara; Regional Irrigation Land and Water Resources Inventory, 2005		Based on Water Resources and Irrigation Development in Ethiopia, 2007	Evaluation of water harvesting schemes in Tigray, 2004

From Table above, it is evident that *river diversion* plays a critical role in the development of SSI followed by *shallow wells*. River diversion is widely used in all the regions visited. *Shallow wells and spring development* are attractive for household level agricultural development. In areas where shallow ground water potential exists it is exploited by communities. Water pumping, farm ponds, deep well exploitation are relatively new technologies and hence were not widely used among communities in the past.

Micro dams are more important in areas where there are less perennial rivers and river flows run during few months of the year. It is mostly practiced in the northern regions of Ethiopia.

Annex 11 to 14 elaborates details of the ranking exercise; technical performance such as easiness of implementation, skill manpower requirement, financial requirement, etc of micro catchment RWH structures and groundwater exploitation; water lifting and water application technologies; and micro catchment technologies respectively. The technologies adopted by the regions were also ranked in terms of their technical complexity and financial requirement for implementation; the result is summarized (Table 2). Accordingly, *trapezoidal pond, hand dug shallow well and spring development* ranked better among water harvesting and ground water exploitation technologies. The most promising SSI technologies are runoff diversion (spate irrigation), upgraded traditional irrigation and river diversions when site conditions are favorable with out considering the cost–benefit analysis. This can also been witnessed from the extent at which they are used in the different regions of the country. Among the few water lifting technologies practiced in the country; treadle pump and motorized pump (small) are the most preferred ones based on technical and capital considerations. Although not widely practiced the limited information obtained show that wind mill is less complex to use where potentials exist.

Table 5: High ranking promising technologies

Source	Technology
Water harvesting	*Trapezoidal pond,*
Ground water	*Hand dug shallow well*
	Spring development
Runoff diversion	Spate irrigation
River diversion	Upgraded traditional irrigation system
	Modern irrigation system
Water lifting technologies	Treadle pump
	Small motorized pump

The result is reasonably in line with the outcomes of the discussion made with key informants in the four regions. It was observed that promising technologies identified by experts in the respective regions (Table 3) are adopted by farmers in a greater scale because of their suitability to the local conditions i.e. addressing farmer's needs, capacities and the service that are realistically available. As indicated in the ranking exercise these technologies are found to be technically simple to set up, operate and maintain; low investment, operation and maintenance costs compared to other technologies. Conservation activities are considered as complementary to ex-situ activities and therefore, they are not considered in the prioritization. It was observed that institutions particularly NGOs through their long experience have specific technologies to promote in their program area. However, there is a general consensus that upgrading traditional irrigation schemes, shallow well development and runoff diversion (spate irrigation), and river diversion are the most promising technologies, and hence can be considered for scaling up depending on the specific conditions of the respective region (Table 3).

Table 6: Most promising technologies by Region

Region	Technology	Justification
Amhara	Upgrading traditional schemes from spring/ river	high level of ownership feeling as they are originally built by the farmers themselves, better operation and maintenance or scheme management; improving structures and make them permanent; high discharge with large command area and hence benefits many farmers
	Shallow well development	where shallow ground water is available provides reliable water; good water quality may have multiple uses including domestic water supply
	Water harvesting	Trapezoidal ponds in suitable agro-ecology with evaporation mitigation measure and availability of market
Oromia	Upgraded traditional irrigation	Shortage of water source could occur and u/s-d/s conflict might be created; established farmers organizations and working procedure;
	Shallow well	Where opportunities exist they are reliable source of water; could be easily constructed with locally available material; can be managed by individual households.
	Runoff diversion/ spate irrigation	In low land semi arid areas traditional runoff harvesting can be done with farmers knowledge and labor
SNNPR	Upgraded traditional irrigation from river	Because of simplicity in operation and maintenance; low cost ; farmers have long irrigation experience
	Shallow well	In high land agro-ecological zones, high value horticultural crops in homestead areas can be grown. At house hold level where potential exist shallow wells, spring development have priority over other technologies.
	Water harvesting structures (Ponds)	Can be constructed with family labor,
Tigray	Modern river diversion	• It can irrigate large area and easy to manage • No sedimentation problem unlike dams except in canals
	Micro dam	• Stores water during wet season including from non perennial rivers to supply water during long dry season • It has a capacity to hold larger amount of water
	Shallow well	• It is possible to irrigate using shallow well during dry season • It provides irrigation water sustainable during dry season unlike other technologies

The impact of these technologies on poverty alleviation; the cost and benefit has been analyzed (Fitsum Hagos et.al. 2008), but the results are reported separately.

Some case studies

Small Scale Irrigation

The topographic map developed by the Ethiopian Mapping Authority (1:50,000) is far less than sufficient for assessment of SSI potential in the country. A more accurate assessment tool needs to be employed to know the potential for small scale irrigation. Existing modern as well as traditional schemes are also not accurately known in number. A more accurate assessment of SSI including traditional schemes can be done through use of higher resolution satellite imagery. Thus, in order to overcome the above-mentioned limitations and provide a benchmark data on irrigation sub sector, IWMI, NBEA has developed a data base for the modern schemes for the use of all stakeholders.

There are different typologies of small scale irrigation that include traditional, spate, upgraded traditional, and modern. Small scale irrigation by and large is community managed or is under private holding. Communities are required to participate at all stages of the development process and they are expected to contribute at least 10% of the capital cost in the form of labor and material. There are good success stories of small scale irrigation overall the country where communities have benefited, but definitely this is not with out difficulties (Box 1).

Box 1: Farmers of Mogdullar Irrigation Water Users Cooperatives are expanding the command area with their own initiative

In Alem Tenna PA the Mogudulla Small Scale Irrigation Cooperative uses river diversion to irrigate their land since year 2005. The cooperative has an estimated 240-300 ha of potentially irrigable land of which about 30-50 ha can be cultivated at any future time. There are about 70 beneficiaries who hold between 0.25 and 0.75 ha of irrigated land individually. Outside the command area there is also a communally owned pump scheme expanded with the initiative of the cooperative. The pump rental rate is about 700 birr/month which is paid by the cooperative and farmers are required to work on the farm, and in case of shortage of labor they also hire extra labor. The farmers reported that the pump scheme is profitable despite its high rental cost. Most of the irrigation is served by a diversion; the main canal is concrete lined and the rest is earthen. At field level furrows are used to apply water to the field with spades being used to guide the water. Canal maintenance is done once in a year by the community themselves.

There are two crops per year in addition to the rainy season. The crops grown include maize, potato, cabbage, onion, tomato, haricot bean, etc. Among these, most profitable crops are onion and sugar cane. RWH technologies are integrated into irrigation development; ponds are used for seedling rising later to be transplanted in to the irrigable land. The rain fed and irrigated crops are grown for both home consumption and for market; with the dry season crops being more market oriented than the rainy season crops. Several organizations like Food and Agricultural Organization (FAO) and Lay Volunteers International Association *(*LVIA*)* trained farmers in the use of water management technologies. There is a committee for water scheduling which is guided by bylaws. During dry season there is disparity in water availability between head and tail reach. This is experienced mostly during the flowering stage of crops, where the water demand is high. There are experiences else where in the country where such problems are mitigated by conjunctive use of ground water. Water related disputes are resolved through team leaders established for the purpose. Farmers report that the water quality is generally good for most crops except for paprika. There is a problem of sediment load which can best be dealt with through integrated watershed management which involves the upstream and downstream users.

They also reported that lack of market and unfair price set by middle men traders for their produce are among the major problems. They have proposed as a solution that farmers cooperative should have a shop in town (collective marketing) for selling agricultural produce. It is reported that at the moment, cooperatives are instrumental to get credits, inputs market for the agricultural produce. It was learnt during the study that farmers had difficulty in getting market for the silk they produced which IPMS-ILRI has helped; one of its objective being improving market conditions to farmers. The food for the Silkworm (castor plant/ *Ricinus communis* and strawberry) is grown in the irrigated area. They are able to sell their produce through the cooperative in which the cooperative assess market alternatives as whole sale. Profit sharing is based on the percentage of share they hold in the cooperative after deductions are made for the services they get. The women explained the benefits of irrigating horticultural crops for their daily cash requirement and provision of better nutrition to their family.

Meeting with Stakeholders at Mogdulla village

According to experts supplementary irrigation is getting increasing acceptance among farmers compared to rain water harvesting with concrete structures because of factors such as cost, water lifting requirement, etc

The problems encountered in SSI include both operation and maintenance. Seepage, collapse of structure, canal crossing, gully expansion, clogging of out lets, lack of maintenance in diversion schemes, sedimentation of reservoirs,, water shortage are some of the problems mentioned. Leakage through diversion structures, field water management, collapse of structures and gully expansion are some of the typical problems under traditional irrigation. Due to weak farmers' organization, operation and maintenance on SSI is generally weak. Farmers are organized as cooperatives. One of the principles of cooperatives is voluntary membership. While the scheme is a single system, exclusion of non volunteer farmers from the organization has created problems in operation and maintenance as well as in water management practices with the scheme. Another severe constraint is lack of provision of irrigation extension service due to lack of conducive organizational arrangement and lack of qualified personnel to provide the necessary service to farmers with regard to irrigated agriculture.

Micro dam

Dams store water during rainy seasons to be used during dry seasons for different purposes. As it is capital intensive and, requires technical designs as well as high operation and maintenance costs, the small scale farmers do not have the capacity to implement by their own. Besides, reservoir sedimentation is a critical issue in dam technology, which makes external technical, managerial and financial support necessary. Occasionally, there are also conflicts arising from resettlement caused by dam construction (Box 2)

Box 2: Tsebayina micro dam in Atsbi (Tigray) provides year round water to farmers

The dam was built to store water from springs located within the reservoir area. Significant amount of water leaks through the dam foundation. This together with other springs along the river is used to irrigate the land in the downstream and on the banks of the river. Crops grown include cereals (barley, wheat), legumes (beans, peas) pasture for livestock, seedlings (apple, olive tree). The average land holding of a house hold is about 0.5ha. Those who use irrigation benefit from three cropping seasons. Usually, cereals are grown during the rainy season while vegetables (potato, tomato, onion, etc.) and other cash crops during dry season using irrigation. Farmers report that pest; especially for beans is the major problem in the area for the last three years. The local bureau of agriculture is supplying improved seeds obtained from seed agency. However, some farmers tend to recycle their own seeds, which results in low productivity and less disease resistant. The extension services are provided by 4 to 6 DAs with different disciplines (agronomy, livestock, natural resource and cooperative) assigned to each PA.

Some farmers pump water directly from the reservoir and river channel to irrigate adjacent farms. Farmers group themselves in 3 to 10 per group to get credit to buy pumps. The pump commonly used in the area has a capacity of discharging 900lit/min, which is expected to irrigate up to 5ha. Among the group, individual farmers who can afford to buy one on their own will leave the group with amicable settlement of their account with the rest of the group.

They have established water users association (cooperatives) and developed bylaws to resolve any conflicting issues among themselves. There is a prevailing conflict over land redistribution, indicating the lack of clear policy directive on land redistribution on the irrigation command areas.

There are also good success stories where land has been amicably redistributed. In some PAs (for instance in Hayelom) with SSI there are Water User's Associations (WUA) which have bylaws and function properly perhaps lessons could be learned from these PAs and applied to others where conflicts exist. On other schemes farmers agreed to remain with their original holding. Those who own large plots rent or share crop (50% each) to others who do not have sufficient land.

A micro dam in Tigray

Ground water exploitation for agriculture

There is no exhaustive ground water assessment carried out in the country except some localized studies for water supply purposes. This and lack of information regarding its sustainable use result in shortage of water in some instances. Ground water exploitation in the country is generally low, but provides good source of water for irrigation and other purposes. There are numerous places where ground water emerges on the surface. In those areas, springs provide a good option for agricultural development. The other source of water for agriculture is deep well. In high land areas like Chencha shallow well development have become good source of water for growing high value crops like apple. Deep wells are usually sunk for domestic water supply. But with increasing development of floriculture in the country deep wells have become part of the agricultural development.

In some areas of SNNPR ground water recharge is increasing with the increase of conservation activities. A vivid example is Humbo Tebela where ground water recharge has increased with the intensive conservation activities in the area. In these areas springs have become potential sources of water for downstream use. Farmers in upstream watershed who recognized this fact are now demanding payment for water. Intensive soil and water conservation works are being implemented in most parts of Tigray which has helped in ground water recharge. Fore example, in Atsbi the community is mobilized at least 20 days per year to do soil and water conservation activities. Gergera watershed is one of the degraded watersheds where the communities were food insecure. Since year 2000 the watershed was protected from human and livestock interference and hence is gradually regenerating. Farmers have started benefiting from the catchment through beekeeping, cut and carry was introduced for fodder to their livestock including increased ground water recharge. However there are still constraints that are encountered during the process of shallow well development. Lack of proper ground water investigation and determination of well yield and spacing have negative consequences (Box 3).

Box 3: Over pumping from shallow wells in Haramaya might have contributed in Lake drying up

Past A shallow well owned by a farmer with five household members was visited in Gende Guto area. It was observed that he grows vegetables such as potato, cabbage, carrot, salad, beet root, onion, etc using water from the shallow well (Box 4) inherited from his forefather. The well was dug in a telescopic shape with diameter about 10m at the top and narrows down to about 2m at the bottom. The well digging is in a stepped manner to avoid caving in as there is neither concrete ring nor masonry lining at the top of the well. In some instances, the wells are found very close to each other as close as 50m radius with overlapping sphere of influence. According to the development agent (DA) The total number of wells in the PA (809 square kilometers) is about 210, which is considered highly dense however, needs to be verified with testing. Intensive pumping from these wells coupled with catchment degradation might have contributed in drying up of Haramaya Lake. Lucrative market in Djibouti has motivated farmers to increase their farm land. This in turn calls for increased water demand and therefore, such development needs to be accompanied by sustainable ground water exploitation studies.

Horticulture development in Haramaya using shallow well

Other constraints include; collapse of the well during excavation in lacustrine environment where the formation is dominantly sand. In such areas excavation should proceed in a telescopic manner (wider at the top and narrower at the bottom) in order to avoid caving in of wells. In vertisol areas such as Becho and Kuyu, wells collapsed soon after rain due to the swelling nature of the soil. It is believed that well capping with concrete ring or masonry may alleviate the problem. There lack of appropriate water lifting technologies is another problem. Water lifting is usually done with rope and bucket but farmers want to have improved and easier technologies. In some instances wells do not have wellhead and manhole cover that expose the well to flooding and contamination

Water harvesting technologies

Given the constraints of lack of funding for small scale irrigation it is important to explore other options that can be implemented at household level to meet the food requirement. It is increasingly recognized by policy makers that due to shortage of capital for large dams and irrigation projects, water harvesting tanks and ponds at village or household levels can be considered as option to improve the lives of rural people with limited external support. The introduction of water harvesting technologies is especially relevant to regions where the problems of environmental degradation, drought and population pressures are most prevalent. Ponds are generally used where other sources of water (GW& Surface water) are short. The adoption of ponds depends on availability of other options. For example in areas where there are alternative livelihood means (coffee, chat growing areas) the adoption level is low.

Some farmers combine two ponds in one to optimize the use of plastic lining. Because of the ponds, farmers able to grow three times per year including the rainy season. The purpose of constructing ponds was to promote supplementary irrigation. However, in areas where there is shortage of water (for example, in Raya), ponds serve for multiple uses – livestock watering, domestic use and supplementary irrigation. The most dominant crops grown using the ponds include; potato, tomato, pepper, onion, cabbage, green maize, and garlic. They are grown principally for cash, but also contribute to household nutrition. According to experts, the income per pond ranges from 3000 to 6000 birr in Gursum, however this is dependant on the market demand of a specific crop in specific area.

Water management is one of the biggest challenges in irrigated agriculture because of non efficient water application methods. Family drip kit and sprinkler irrigation can be used to improve water use efficiency. They are among the most efficient water application technologies that are practiced. Some farmers use multiple drip kits to maximize the area irrigated (Box 4). The cost of one FDK is 801 Birr and credit is available for those who want to buy. In both cases, water free from sediments should be used so that the emitters may not be clogged.

Box 4: Farmers innovations on the use of family drip kits in Haramaya woreda

Some farmers wanted to irrigate larger area and have tried to maximize the capacity of family drip kits (FDK) with their own innovations. Normally, One FDK has three laterals, irrigates only 300 square meters. A farmer near Haramya town installed seven laterals in opposite sides of a tanker to irrigate about 2100 square meters as it is reported by the woreda experts. Initially, the storage tank was being filled with a treadle pump. However, the capacity of the pump was not adequate to meet the needs and hence they had to resort to small motorized pump. In some instances the predetermined spacing of FDK emitters does not match with the spacing of plantation (ex, chat) because of these farmers suggest having the emitter and the puncher to come independently so that they could make the drippers that fits their requirements. It is generally recommended that farmers use optimum spacing of crops that they opt to grow.

There are also areas where failure has been noted. There were ponds without water due to in appropriate site selection or seepage loss; ponds floated due to ground water rise. Experts agree that it has been a learning process where both farmers and experts have acquired a lot of experience in the process of implementation in the past few years. In semi arid areas water loss from ponds through either seepage or evaporation is a major problem. Farmers build grass hatched hut over the ponds in order to reduce evaporation loss. Mud mortar is a pond lining technology to reduce seepage loss where caolinite dominant red clay soil (locally called kuisa) is mixed with cement in 1:6 ratios. Soil type is among the dominant factor for the success or failure of this technology. Generally, in areas where there are sandy soils or vertisoils, the chance of success is less.

In dry areas with high evaporation loss, dome shaped structures are often successful. Dome and Hemispherical concrete structures are found Kobo and Woldia (Guba lafto) areas. In these areas, water is used to irrigate cash crops and domestic water supply. Farmers in Kobo area sell their harvested water for domestic uses at about 2 birr/20 liter according to experts.

Spate Irrigation

In Ethiopia, spate irrigation is mostly practiced in East Tigray, East Hararghe, around Konso and Jinka areas. Oromia Region has in recent years adopted a policy of promoting spate irrigation. Oromia Irrigation Development Authority (OIDA) is embarking on a massive spate irrigation development, which involves upgrading of traditional and development of new ones in the entire Region. This is because spate irrigation is considered to be easily adoptive by farmers as it is cheaper. Upgrading of traditional spate irrigation was underway in Fedis areas, but farmers were impatient to wait for the official handover of the modern system that they have started to use it. In Gursum woreda, currently site selection, study and access road construction by farmers have been completed for Ariro 750 ha, Samkala 1500ha, Harobati 200 ha awaiting budgetary allocation for the commencement of construction during the coming new year. Farmers in Dodota used to experience repeated crop failures due to recurrent drought in the region. In response to this effect the 5000 ha Boru Olloo spate irrigation development in Arsi was started around mid-2007 and is now well in progress. During the field visit those farmers who got water reported that their crops have survived the dry spell of this year because of the project (Box 5).

Box 5: Boru Ollo modern spate irrigation relieves farmers in Dodota from climate variability problems

Boru Olloo spate irrigation located in Arsi, Dodota Sire woreda was started in mid 2007. The long term plan of the project is to provide water to farmers in Dodota area who commonly suffer from frequent drought so that they can irrigate about 5000 ha. In the short term it will provide supplementary irrigation to 3000ha. Farmers in the area use wild flooding to irrigate crops with out proper water management practices, which implies their limited experience in on farm water management. There is a need for further soil investigation to understand salinity conditions before and after introduction of irrigation. It is advisable that farmers get in field water management and sufficient extension support to maximize the benefit from the planned spate irrigation. Further investigation sediment yield of the river catchment and its impact on the project may be required to look for timely measure. In the long term there is a plan to transfer water from Keleta River to Boru River to change the scheme from spate irrigation to diversion scheme that could benefit farmers all year round.


Modern spate irrigation in Boru Olloo previously rainfed, Oromia

Soil and Water Conservation technologies

Most highlands of the country are highly degraded through deforestation, overgrazing, improper farming practices which lead to food insecurity. This situation has been further aggravated by frequent drought. Rehabilitation of marginal lands through appropriate soil conservation measures is increasingly recognized so that it contributes to agricultural production. Promoting sustainable farming by adopting suitable soil and water conservation technologies may enhance food security. Some soil and water conservation technologies have been traditionally practiced by the community since antiquity where as others are introduced in recent years. Promotion and adoption of new technologies and lessons of good practices are important to the sustainable use of the land.

Experience shows that issues of land degradation require holistic approach rather than individual interventions. Although individual based technologies generally show better success, soil and water conservation measures generally require community actions. Soil and water conservation has been a tradition to communities like Konso, where hill side bench terraces are widely used. Soil and water conservation is embedded in farming practices in Tigray, where most areas have been well terraced.

Up scaling and sustainability of technologies

Consultations with experts have revealed that, there are some constraints to scale up the promising technologies identified. Some of these constraints are summarized in Table 4.

Table 7: Summary of constraints to scale up promising technologies

Technology	**Constraints for scaling up**	**Recommended measures**	**Remark**
Upgrading traditional schemes	Technical and financial capacity, water scarcity due to increased area, poor water use efficiency		Poor agronomic practices, pest management
Shallow well development	Poor site selection, poor construction methods, lack of suitable water lifting mechanism.	Techniques of well digging, appropriate water lifting techno,	Crop water management
Runoff diversion/ spate irrigation	Can only be used where there is an opportunity		
Water harvesting structures	Seepage, evaporation, sedimentation, estimation of catchment yield		
Modern river diversion	Lack of strong farmers organization, limited support services		
Micro dam	-Lack of capital to scale up to wider communities -Sedimentation of the reservoirs, -Conflict due to land reallocation -Lack of skilled manpower for operation and maintenance		
Water lifting (treadle & small motorized pump)	-Motorized pumps are too costly to farmers, -difficulty in availability of spare parts		

In addition to the technical constraints, there are also institutional and policy related issues that are affecting the scaling-up of agricultural water management technologies. These include lack of promotion works, affordability of the technologies, access to market for input and outputs, institutional issues, policy environment, technical challenges, socio-economic, environment and health related issues outlined below need to be attended.

Promotion

In order for people to perceive the benefit of a new technology, they should have detailed information not only on the benefits but also on the constraints. The problem that hinders dissemination of information on water harvesting is insufficient documentation. WOCAT-Ethiopia is currently doing a commendable job of building a database mainly on soil and water conservation practices. However, simple manuals, booklets, brochures, and posters on promising technologies are in need. These can be used to enhance awareness among the farming community, experts and policy makers. They can also be used by development agents to implement the technologies with minimum external support. These may require building of synergies among various stakeholders in research, policy, advocacy and development partners to facilitate development of the above tools. Such synergies could be achieved by enhancing collaboration, networking, partnership and information sharing. The Ethiopian Rain Water Harvesting Association (ERHA) is endeavoring to play such a role

Affordability

Some technologies are some times are beyond the financial and technical capacity of farmers. In such circumstances, external interventions either from the government or NGOs are required to support the farmers both technically and financially. However, farmers can contribute in kind such as construction material and labor. Public-private partnership is also vital in successful adaption of water harvesting technologies.

Most farmers have little capital to invest and this limited resource should only be spent on a proven technology. When conditions allow farmers prefer to employ their labor rather than invest their capital on any infrastructure therefore, technologies that require more labor investment will have preference over those capital intensive ones. For example, dome shape cistern is the most expensive type of water harvesting structure where the labor contribution is only about 20%. Hand dug shallow well is the cheapest where the labor contribution is more than 35% (Table 4). In some instances ponds are beyond the capacity of individual households to construct– in terms of labor, land, and other resources. For example, construction of pond (size 12*12) requires labor, land and cash. In some instances, ponds occupy productive land and because of this farmers are uncomfortable. Price escalation of construction materials like cement and other factory products are beyond the purchasing power of farmers to scale up technologies including traditional ones like flood diversion/spate irrigation.

Based on the cost build up shown in Table 5 the percentage cash and labor contribution for construction of house hold water harvesting structures is shown in Table 4. Although the cost of water harvesting structures are given in Table 5 below from one region it could provide cost comparison of different water harvesting structures with other regions.

Access to market

Access to market is a critical precondition for success of any technology. If there is no market it is discouraging to farmers to grow more. Because of varying local conditions and changes in the road network differing market opportunities exist in different locations. According Rebeka (2007) the benefit found from the high value and perishable commodities due to RWH depends on market and infrastructure accessibility, and diversification in the types of the crops. Thus, efforts should be made to assess various agricultural commodities as well as giving emphasis to marketing extension, especially in facilitating markets to farmers.

Market becomes a problem where there is no major urban center in the area. During our field visit market constraints have been reported in many localities of the country including schemes around Debrezeit, Atsbi, Alamata, Fogera, etc. Even though farmers report that their livelihoods have improved through water harvesting measures, they face market constraints while growing vegetables and other crops in sufficient quantity. Sometimes due to lack of market information farmers tend to grow similar crops beyond the limits of the market demand. The level of demand and the extent of availability in a particular area determine the type of crop and the price setting. Hence availability of information to high value crops in a particular area is an important input to farmers. For example, vegetable farmers in Haramaya area have widely adopted shallow well technology because of the lucrative market in Djibouti and the same is true for other areas too.

Farmers also complain that they are being exploited by middle men and feel that they do not get what they deserve. These middlemen are giving very exploitative and unreliable terms at the same time; they are in a position to dictate the market. Normally, for larger produce farmers sell on credit basis to middle men and get their money after it is sold. It is important that farmers get what they should deserve and in this regard absence of strong cooperatives in most schemes visited is a disadvantage to farmers.

Institutional issues

The responsibility of WH implementation, supervision and monitoring is divided among different government organizations and NGos. Strong coordination among these institutes is a paramount importance. The institutional set-up and accountability issues on WHT vary from region to region and they are not generally stable. Frequent institutional restructuring and staff turn over are the most critical problems for sustainable development of the sub-sector. As a result, there is confusion on mandate, resulting in some cases of scheme failure due to lack of accountability in provision of operation and maintenance and other services. In most cases, the participation of the private sector in provision of services is generally poor. Creating the enabling environment for the private sector and providing the necessary capacity will motivate the private sector to play its role in increasing agricultural water productivity.

Policy environment

Land tenure was found to hamper promotion of RWH, where land users invest minimal resources on the land for fear that it may be reallocated to others. In some PAs there are conflicts still arising from land redistribution that occurred when dams are constructed and command areas are developed. Farmers lost land when dams were constructed and there are no clear compensation mechanisms in place. The situation may become much worse with the growing realization of the benefits of WH especially for resource poor small scale farmers. Such conflicts may adversely affect promotion and adoption technologies. Absence of land use policy in the face of dwindling farm size is a critical problem for success of WHT. Currently, conflict resolution on land re-distribution very much depends on farmers will and ability to resolve the issue.

In some areas of Northern Ethiopia land certification is being piloted. Land Certification requires farmers to conserve the natural resources available with in their holding. If farmers don't comply with conservation measures, the land will be confiscated. In some of the pilot areas like in Amhara Regional State the main challenge lies in implementation of the certification, which may require putting in place detailed enforcement guideline in order to reverse the natural resources degradation condition. Incentive mechanism such as prize award is another means to encourage farmers to embark on conservation measures. Land certification is an encouraging attempt towards enforcing conservation activities. However, comprehensive policy framework guiding the promotion, development and adaptation WH systems in the country is generally lacking.

Downstream-upstream conflicts could also be reduced if upstream users harvest water allowing adequate water to reach downstream users. However, upstream water harvesting may also lead to reduced river flow, which could also cause conflict with downstream users. During dry season there is disparity in water availability between head and tail reach of an irrigation scheme. Upgrading an irrigation scheme usually increases irrigation command area which may result in water shortage; and competition for water could cause conflict among communities. In view of ensuing competition and conflicts over limited water resources urgent policy attention is needed.

Technical challenges

AWM technologies offer tremendous opportunities for improved agricultural productivity and increased household income. However, there are a lot of technical and management challenges and threats reported in the literature as well as by experts affecting the sustainability of AWMT. These technical challenges include feasibility of technologies, the management challenges that farmers face with the introduction of new technologies, operational and maintenance problems; lack of availability of spare parts, environmental problems such as public health and pests.

Poor workmanship and inadequate technical skills could negatively affect technology promotion and adoption. A case in point is ponds constructed on black cotton soil in Ada' woreda with out any lining material have negatively affected the adoption of ponds in the entire area. All the water contained was drained while the soil was cracking. Similarly, there are incidents where under ground tanks have failed due to leakage caused by cracking, unable to with stand uplift pressure from ground water level rise. The performance of many WH structure is also low due to inadequate maintenance

From our fieldwork, we have observed that there are serious shortages of lining material in areas where ponds are well received. On the other hand, we have also witnessed plastic lining material being forced on farmers and are being used for other purposes like roofing material as shown in the Fig.2.

Figure 2: Geo-membrane used as roofing material, Alamata

Socio-economic factors

It is important that the beneficiaries participate at every stage of project implementation. Unless communities are involved actively starting at early stage of planning, the success of the program becomes unlikely. They should be consulted about their priorities and their needs should be taken into account. Indigenous knowledge developed and improved over time through accumulated experience are found to be more sustainable to the locality. Examples of such practice are hillside terracing and spate irrigation found in northern Ethiopia and else where in the country.

We have witnessed ponds constructed in high rainfall areas being abandoned; more ponds have been constructed than required because of the need for more food aid. Problem of water logging in hillside trench due to soil type and resistance of farmers at the initial stage of the program implementation are among the noted problems. The reluctance of farmers to invest in permanent water harvesting structures on land that will not remain in their holding for long is hindrance to acceptance.

To mention some of the general draw backs that hinder acceptance of conservation measures is that they are labor demanding, loss of productive land, financial requirement and lack of access to market. Family labor is sometimes hampered by in adequate food supply; hiring labor in many cases is difficult due to economic status. In such cases less labor and capital intensive technologies could be more suitable. For example construction of underground tanks like dome, bottle shaped, etc are not easily made by poor farmers without a strong credit service because of the high investment cost.

Although the Water Resources Policy advocates full cost recovery it is not yet realized in most irrigated schemes. However, some have managed to recover the cost of operation of maintenance like Mogudulla small scale irrigation cooperatives in Alaba.

Environment and health

In general water harvesting systems are environmentally friendly, but there are some minor concerns such as increased mosquito and snails, soil erosion along inlet channels, reservoirs, poor water quality, and risks of drowning, among others. Though positive environmental impacts outweigh the outlined concerns, they should not be ignored. Improved environmental conservation activity is required in terms of reduced soil erosion, improved soil fertility, agro-forestry and afforestation of hill slopes.

Table 8: Cash and labor contribution of water harvesting structures

WH structure	Cash contribution (%)	Labor contribution (%)	Relative cost
Hemisphere	82	18	7.2
Dome	80	20	14.7
Geomembrane	68	32	4
Pond	-	100	2.5
Hand dug well	65	35	1

Source: Based on table 5

In roof water harvesting technologies flush diverters need to be provided in the delivery system to divert the first runoff at the beginning of each rain. Cleaning tanks, say annually, improves water quality provided any remaining disturbed sediment is allowed to resettle for several days before the tank is used again.

Runoff is taken from the road, where livestock droppings, excrements and garbage are common. Without proper education and extension work, ponds can create serious health problems (Rami, 2003). This is very important because households use water harvesting structures such as ponds as source of domestic water exposing them to water related diseases.

Studies show that the experience with water harvesting is limited, environmental side effects such as salinity of the soil is not observed (Yazew et al., 2007). However, the same study recommends that farmers using wells would have to implement necessary measures to minimize effect of salinity including irrigation schemes with storage and river diversion facilities.

Table 9: Construction cost of water harvesting structures

WHSs	Proposed Volume in m^3	Total No. constructed in 2003 & 2004*	Cost of construction a structure				Remark
			Cash cost	Labour cost	Cost/structure (cash + labour cost)	Total cost	
Hemisphere	60	6468	3000	646	3646	23582328	Labour cost was assumed according to the norm.
Dome	60	401	6000	1467	7467	2994267	Information on labour cost was as to the farmers
Geomembrane	60	10114	1380	646	2026	20490964	Labour cost was assumed according to the norm.
Pond	118	45508	-	1270	1270	57795160	The size of ponds varies from 60-540m^3
Hand-dug Well	-	173949	320	176	496.00	86278704	The volume was totally varied from place to place
Total						**191,141,423**	

N.B.

1. The norm for person/day was 0.5-0.75m^3. Thus, the average was assumed to be 0.65m^3
2. Labour cost (person/day) was assumed to be Birr 7.00.

Source: Y.Afework, 2006; EPLAUA

Table 10: Labor requirement of soil and water conservation measures

Activity	**Unit**	**Work norm**
Soil bund	Km	70 pd/km
Stone bund	Km	150 pd/km
Fanya juu	Km	250 pd/km
Water way	Km	800 pd/km
Cutoff drain	Km	400 pd/km
Gulley plugging	Km	
Gabion checks	Km	1 pd/km
Loose rock checks	Km	1 pd/km
Brush wood checks	Km	1 pd/km
Sand/soil bag check	Km	1 pd/km

Source: Proposal to accelerate the integrated watershed management implementation in Koga Watershed; MoWR, 2002

Social equity: Gender sensitive water development technologies can significantly enhance the productivity if women are involved through out the process. In practice, Women farmers working on irrigated land mostly share cropping, or hire labor and usually lack capital to invest on their land. An evidence of such practice is Chelecot drip irrigation in Alamata where all female headed households share-crop their farm plot.

Proper irrigation development endeavor is generally location specific, capital intensive and the service can not be provided to all sections of the society. Regassa E. Namara (2007) confirms that income inequality among households with access to irrigation is worse than that of those with out access. In contrast, household level water harvesting structures are simple, can be constructed by family labor and therefore can generally be done when individual farmers are ready to have it with minimal external support.

It is generally recommended multiple use approach should be adopted that preferably can target women and the poor to stimulate productive water use and technologies that favor IWRM principles. For example when ponds are located near the homestead, easy for women to manage and water can have multiple uses; can generate cash from horticultural crops.

Extension and inputs

Farmers feel that the current system of input delivery for irrigated agriculture is unsatisfactory and, acts as a severe constraint on their production. Timely delivery of input will play one of the most decisive roles in the success or failure of the WH effort in the country. As observed at all WH and irrigated sites and from discussions held with experts, the agricultural extension aspect is very weak and lags far behind the development. Provision of poor extension service is attributed to lack of qualified personnel (for example only one trained irrigation agronomist in the entire SNNPR) to provide the necessary service to farmers in the all the regions visited; DAs are not well trained in relation to irrigated agriculture to enter-face between experts and the farmer. This coupled with high staff turn over; those trained as DA or higher level being transferred to some other task has made the situation worse.

The extension media like demonstration, training, etc in most cases are non existent even if available they are not appropriate. Water harvesting structures such as trapezoidal ponds could not be scaled up due to low technical know how of DAs, farmers dependency syndrome and shortage of geo-membrane in areas where it is well received.

The DA will remain the pivotal interface between Government and farmer, but the Office of Agriculture has to be in a position to support DAs with emphasis to WH technologies. In the longer term, reform of the extension service with respect to irrigation and drainage is to be commended. Training of agricultural staff and DAs in irrigated agriculture and strengthened irrigation extension services to the farmers are very decisive.

Training and capacity development: Farmers reported that they receive training once or twice in a year and this is not sufficient. They need training particularly on how to grow vegetables, water management and strengthening the capacity of WUA, since most of these technologies are new to the farmers. Marketing, operation and maintenance and how to reduce post harvest losses, pest management are very important in improving crop productivity. Training materials in product marketing, irrigation extension, cooperative financial book keeping/auditing and monitoring are all important.

Capacity of Woreda experts at zonal and regional level needs to be improved in terms of number and qualification. Some of the training requirements include:

- Introduction (Agronomy with emphasis on horticultural crops, water management, marketing);
- Site selection (runoff estimation, specific site selection locally available materials - soil type and crop water requirement, and estimating potential irrigable area);
- Training of Trainers (Woreda experts, DAs, farmers) on construction methods of WH structures should be carried out so that they go back and the training program is wide spread at all levels.
- Reporting

Monitoring and Evaluation system: M&E system should also collect information and compile reports on a monthly, quarterly and annual basis at all levels. The M&E system should be established with the following objectives:

- Improve productivity of AWMTs
- Improve water use efficiency of AWMTS
- Ensure repay and recurrent investment for water harvesting system

In most places visited there are no M&E systems; even if there is monitoring and evaluation system is biased toward civil works. There should be a system to identify veritable and measurable impact indicators that are foundations of an effective monitoring system. Institutionalizing the M&E in the respective water related institutions should be considered in order to make it a routine exercise. In order to be effective and make the monitoring system workable, a simplified record keeping system should be introduced to WUAs on each scheme.

In conclusion, lessons that can be drawn from the above for scaling up of promising technologies include awareness creation among communities, inter regional cross visits where good practices exist, upgrading technical skills through training, demonstration of benefits of technologies before initiation of program implementation; and improvement of access to market are issues that require due attention.

Conclusions and recommendations

In practice, many technologies were seen successful and few with out success. From lessons learnt in conducting this study the following general conclusions and recommendations can be made.

1 AWM technologies are generally successful in areas where there is low rainfall to increase household agricultural production for food, cash crops, and livestock production.

2 Adoption of small pumps by farmers is increasing at an alarming rate. The use of pumps can significantly contribute to food security at household level. Such use can be further enhanced if cost of pumps is lowered through tax exemption or create an enabling environment for local manufacturing. Provision of electricity to rural areas with affordable price will also enhance the use of motorized pumps.

3 In areas where there is a potential for shallow well development it has preference over other technologies and found to be more sustainable if supported with

watershed conservation activities. In areas where the water source is less than 6 meters, treadle pumps offer potentially suitable technology to adopt in conjunction with storage structures.

4 There are evidences that success and adoption of technology is highly linked to market. Therefore, it is important that physical infrastructure is developed and farmers get up to date market information to enhance their access to market. In this regard, strengthening the capacity of farmer's organization is critical in order to protect farmers from being exploited by middle men.

5 Monitoring and evaluation of positive and negative socioeconomic impacts, assessing cost-effectiveness, piloting of technologies before program implementation, and sharing lessons learned among stakeholders needs to be strengthened which is currently almost non existent.

6 Nexus between conservation activities and water harvesting and its integration to a catchment approach is generally missing due to fragmented institutional responsibilities; although there are changes still requires some improvement. An integrated approach that includes soil and water conservation, crop and livestock management system together with other income generating activities.

References:

Amaha, R. and Gebremedhin, B. (2006?). Impact Assessment of Rainwater Harvesting Ponds: The Case of Alaba Woreda, Ethiopia. Paper presented in International Symposium on impact of irrigation on poverty and Environment.

Awulachew, S.B.; Yilma, A.D; Loulseged, M.; :poslamd;, W.,Ayana, M.; Alamerew, T.2007. Water Resources and Irrigation Development in Ethiopia.Colombo, Sir Lanka: International Water Management Institute.78p. (Working Paper 123).

B. Anenia; F. Abay; Y. GebreMichael. Proceedings of Anglophone Regional Workshop (Feb. 6-11, 2000) Mekelle, Tigray - Ethiopia. 53-58.

EU Evaluation, 2004; Irrigation development; Evaluation of the water harvesting schemes component of the EC funded programmes IFSP 1998 and IFSP 2000 in Tigray regional state Working paper1, 3, 4 .

EU Evaluation, 2004; Final evaluation report; EU SCR framework contract: Evaluation of the water harvesting schemes component of the EC funded programmes IFSP 1998 and IFSP 2000 in Tigray regional state, Ethiopia.

FAO(Food and Agriculture Organization) Land and water digital media series No.26, Training course on WH for improved agricultural production.

FAO (Food and Agriculture Organization of the United Nations) 1986; Ethiopian Highlands Reclamation Study, ETHIOPIA FINAL REPORT, Volume 1, Report prepared for the Government of Ethiopia .

G. Alem,1999. Rainwater harvesting in Ethiopia: An overview. 25th WEDEC Conference.

Gould, P.J and E.N. Petersen, 1999. Rainwater catchment systems for domestic supply: Design, construction and implementation. IT Publication Ltd., London, UK.

Hagos, F. Eyasu Yazew, Mekonnen Yohannes.; Afeworki Mulugeta,.; Girmay G/Samuel, Zenebe Abreha, Gideon Kruseman , and Vincent Linderhof (2007a). Impact of small scale water harvesting on household poverty: evidence from Northern Ethiopia. A book chapter. Edward Elgar Publishers. Forthcoming.

Hagos, F., M. Yohannes, V. Linderhof, G. Kruseman, A. Mulugeta, G. G/Samuel, Z. Abreha (2007b). Micro water harvesting for climate change mitigation: Trade-offs between health and poverty reduction in Northern Ethiopia. Submitted to Environment and Development Economics.

Hagos. F, J. Gayathri, Awulachew, S. B. M.Loulseged, and Aster Denekew. Poverty Impacts of Agricultural Water Management Technologies in Ethiopia, 2008

H.P.Ritzema; R.A.L Kselik and Fernando Chaduvi. Irrigation Water Management Training Manual No. 9, Drainage of Irrigated Lands, FAO, 1996.

J. Kinaga, 2006; the Adoption of Micro Irrigation Technologies (Private Sector Participation in Irrigation Development), the KickStart Experience, Kickstart International, Nairobi.

J.Kinaga, 2006. The adoption of micro irrigation technologies. Kickstart international, Kenya

Kibwana, O.T. 2000. Farmer innovators and their innovations in land husbandry in Tanzania.

L.Desta, Caruchi, V., Asrat Wendem-Agenehu and Yitaw Abebe (eds). 2005. Community Based Participatory Watershed Development: A Guideline. Part 1&2; Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Mati, B.M.; N. H. Hatibu and K.P.C Rao. Preparation and Start-Up Phase Project (Pre-IMAWESA), 2006.

Mburu D.M. 1989. The role of sand dams in water supply in arid areas (Machakos). Unpublished M.Sc. Thesis. Department of Agricultural Engineering, University of Nairobi and London, UK

M.G, Klaij. Vertisols Management Training Manual; EARO, 2001.

Ministry of Water Resources, 2002. Water Sector Development Programme, Ethiopia.

Oweis, T., D. Prinz & A. Hachum. 2001. Water Harvesting: Indigenous Knowledge for the Future of the Drier Environment. ICARDA, Aleppo, Syriea. 40 pp.

Rami, H. (2003). Ponds filled with challenges Water harvesting – experiences in Amhara and Tigray. Office for the Coordination of Humanitarian Affairs (OCHA) Ethiopia. *Assessment Mission: 30 Sept –13 October 2003.*

Reij, C., P.Mulder and L.Begemann.1988. Water harvesting for plant production. World Bank Technical Paper No.91, Washington D.C.

Rockstrom, J.2001. Water resources management in smallholder farms in Eastern and Southern Africa: An overview. Phys. Chem. Earth (B), 25(3): 275-283.

R. Namara, S. B. Awulachew and D. J. Merrey (IWMI), 2006*;* Review of Agricultural Water Management Technologies and Practices.

S.N. Ngigi, 2003; with contribution from Nicholas Kiggundu, Ephraim Alamerew, Fredrick M. Ndege Fredrickk I. kihara, Keziah N. Ggure, Berhanu Fentaw, Reuben K. Muni, Patrick Lameck, Paul M. Kimeu, Seid Ali; Rainwater Harvesting for Improved Food Security: Promising Technologies in the Great Horn of Africa .

S. S. Magar, Balasaheb Sawant Konkan, 2006; Best Practices and Technologies for Agricultural Water Management, Agricultural University, Dapoli, India.

T. Erkossa; G. Ayele. Indigenous Knowledge and Practices for Soil and Water Management in East Wollega, Ethiopia, 2003 .

W. Critchley, 1991; Center for Development Cooperation Services, Free University, Amsesterdam; K.Siegert, 1991; Land and Water Development Division, FAO.

W. Critchley, 1991; Water harvesting, a manual for the design and construction of water harvesting schemes for plant production, FAO.

W. Teshome, 2006; Irrigatiion practices, Interventions and Farmer's Life-Words in Drought Prone State of Tigray, Ethiopia.

Y. Belete, 2006; Current experiences on existing small scale irrigation.

Yazew, E., G/Samuel, G., Hagos, F., Kruseman, G., Linderhof, V., Yohannes, M. Mulugeta, A., and Abeha, Z. (2007). Water harvesting for poverty reduction and sustainable resource use: Environmental and technical issues. PREM working paper # 07/02. Institute of Environmental Studies, Vreij University. The Netherlands.

Y. Gebremicheal; 2004. Water harvesting technologies in assuring food security: Lessons from the pastoral areas of Somali Region, Ethiopia.

Y. Wondimkun and M.Tefera, 2006; Household Water Harvesting and Small Scale Irrigation Schemes in Amhara Region.