Roles, Constraints and Opportunities of Small Scale Irrigation and Water Harvesting in Ethiopian Agricultural Development: Assessment of Existing Situation[1]

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Abstract

Ethiopia is one of the largest countries in Africa but it is also one of the poorest. It has tremendous land and water resources, but has had mixed experiences with promoting irrigation and other modern agricultural technologies. Promoting small-scale irrigation (SSI) and rainwater harvesting are central to Ethiopia's new policy and strategy on agricultural and rural development. This paper deals with an assessment of the impacts of these interventions, identifies further opportunities and constraints. In some regions, there is evidence that irrigation has created some positive impacts: better opportunity for production, better income, reduction of risks and hence generated benefits for poor rural communities. Despite successes, there are a number of failures that need attention. There is a general perception in all regions of Ethiopia that the current trend of low performance of some of the small-scale irrigation schemes is related to flawed project design and lack of adequate community consultation during project planning. Since small proportion of the potential is used and most of the SSI programs are currently in the planning stages, and are yet to be implemented, these conclusions should be seen as providing a unique opportunity to learn from these drawbacks. If ignored, well-intended efforts of governments and NGOs are likely to continue falling short of their intended impacts.

Introduction

Ethiopia is one of the largest countries in Africa. Covering a land area of 1.13 million km^2, it is the second most populous country in sub-Saharan Africa (SSA) (and third on the continent) at about 70 million people. According to the World Bank (World Bank, 2003a) per capita income in 2001 was only $100 per year. The population has been increasing by about 3.0 % annually in the 1990s. Child mortality is at 116 deaths per 1000 live births and child mortality rate is at 184 deaths per 1000 live births (Heins, F et al, 2001). The population structure shows that persons of 0-14 years made up 43.8% of the population in 2000 (Muluneh, 2001). The dependency rate is also higher than in other African countries. It is estimated that about 100 persons in the productive ages (15-59 years) have to support 124 dependents in terms of food, clothing, health and education (Dagnew, 2000). This exacerbates food insecurity and poverty. A population density of 17.5 in 1950, increased to 34.5 (1984), 45.5 (1994) and to 57 persons km^{-2} in 2000 (Muluneh, 2001). Population density, and hence population pressure on resources, varies from region to region. Eighty-five percent of the population is rural. The incidence of poverty in the rural areas is higher than in urban areas, 47% and 33% respectively. About 49% of the total population is considered 'under-nourished'. Fifteen to twenty percent of the rural households are female-headed.

Ethiopia's topography can be broadly grouped into uplifted central highlands, tapering into peripheral lowlands that also include the Rift Valley. Most of the country consists of high plateaus and mountain ranges with precipitous edges dissected by numerous streams in the center, and rolling plains all along the periphery (Mati, 2004). The lowlands are relatively hot,

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with annual rainfall varying between less than 200 to 800 mm and average temperatures of 25° C. The climate in the highlands above 1800 m is mild and annual rainfall ranges from 800 to 2200 mm, with a mean annual temperature of 15° C. The highlands above 1500 m altitude constitute 43% of the country and accommodate 88% of the human population, over 65% of the livestock, comprise 90% of the cultivated land and nearly 100% of the industrial forest cover (Bekele-Tesemma, 2001). The dry lands occupy about 70% of the total landmass and 45% of the arable land. They are characterized by a highly fragile natural resource base; soils are often coarse-textured, sandy, and inherently low in organic matter and water-holding capacity, making them easily susceptible to both wind and water erosion. Crops can suffer from moisture stress and drought even during normal rainfall seasons. Farm productivity has declined substantially and farmers find themselves sliding into poverty (Georgis, 1999).

Ethiopia covers 12 river basins with an annual runoff volume of 122 billion m^3 of water with an estimated 2.6 billion m^3 of ground water potential. This amounts to 1743 m^3 of water per person per year: a relatively large volume. But due to lack of water storage capacity and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year with frequent crop failures due to dry spells and droughts. Moreover, there is significant erosion, reducing the productivity of farmland.

Agriculture is by far the dominant sector. Most of Ethiopia's cultivated land is under rainfed agriculture. Less than 40% of the arable area (13.2 million ha, or 12% of the total land area) is currently under cultivation (ADB, 2003). There is progressive degradation of the natural resource base, especially in highly vulnerable areas of the highlands, which aggravates the incidence of poverty and food insecurity in rural areas. Ethiopia imports about 15% of its food. The government has designed a comprehensive food security strategy that targets the chronically food insecure especially in highly vulnerable areas: marginal and semi-arid areas that are largely moisture deficient, including pastoral areas, with high population pressure. If such measures can be effectively and sustainably implemented can make significant difference.

<u>Existing Situation in Ethiopia</u>

The Poverty Vicious Cycle

The current situation in rural Ethiopia is a "vicious cycle" that includes the following dimensions: population growth→extending agriculture and livestock into less and less favorable land, deforestation to obtain energy and more agricultural land →land and water degradation→poor productivity, food insecurity→poverty→poor health, malnutrition → inability to invest in maintaining or improving land productivity→further degradation, etc. How to transform this "vicious cycle" in to a "virtuous cycle" is the key question that needs to be addressed.

Problems in Agricultural Water Management and Investment Opportunity

The major problems associated with managing agricultural water include:

- Long dry spells (leading to crop failures)
- Drought (three major droughts in 30 years)
- Huge water resources potential but with spatial and temporal variability
- Unutilized due to lack of infrastructure, lack of investment capital, transboundary nature of the riversè stagnation to increase production and productivity using water resources
- Other problems related to supporting institutions, water use rights, management, etc

Rural Ethiopia exhibits a huge variation along a number of social and economic dimensions: ethnic group, religion, and economic status are just three. After infrastructure development such as roads, investments in irrigation emerge as key factor triggering rural upliftment. Moreover, the multiplier effects of investments in agricultural intensification, for example for irrigation, are considerable (Hussain and Hanjra 2004). Studies reveal that for each dollar invested in agriculture, the value of economic activity in forward and backward linkages including input supply, trade, export, and processing adds another two dollars return. However, for theses benefits to be realized especially in the African smallholder context, smallholder irrigation must satisfy the following conditions (Shah et al., 2002):

- Irrigation must hold out a promise of making significant improvement in the livelihoods and food security situation of the irrigation farmers, i.e., it must be central in their livelihood strategies, and a large proportion of household income must come from irrigation (this relates to optimal plot sizes, crop choices, etc. that enhance viable production);
- The cost of sustainable farmer management of the schemes (including infrastructure, technology, water user associations, etc.) must be an acceptably small proportion of the income derived from irrigation, i.e., benefit cost ratios must give incentives that facilitate rational production decisions;
- The schemes must have a certain level of access to institutional support services, including access to inputs, output markets, credit, extension, institutional framework defining and enforcing secured and use rights to land and water

Irrigation In Ethiopia

Irrigation is one means by which agricultural production can be increased to meet the growing food demands. Increasing demand can be met in three ways: increasing agricultural yield, increasing the area of arable land, and increasing cropping intensity (number of crops per year). Expansion of the area under cultivation is a finite option especially due to the marginal and vulnerable characteristic of large parts of the country's land. Increasing yields in both rainfed and irrigated agriculture and cropping intensity in irrigated areas through various methods and technologies are viable options for achieving food security in Ethiopia. If the problem is failure of production as a result of natural causes such as dry-spell, drought, etc., agricultural production can be stabilized and increased by providing for irrigation and retaining more rainwater for *in situ* utilization by plants.

The challenge that Ethiopia faces in terms of food insecurity is associated with both inadequate food production even during good rain years (problem related to growth of population), and natural failures due to erratic rainfall. Therefore, increasing arable land or attempting to increase agricultural yield alone cannot be a means to provide food security in Ethiopia, due to environmental impacts (expansion into marginal land, deforestation) and unpredictable natural factors (unpredictable climate). Ethiopia has also to combine these with enhancing water availability for production and expansion of irrigation that can lead to security in terms of getting a reliable harvest as well as intensification of cropping (producing more than ones per year). This should be combined with improved partitioning, storage and soil water-retention capacity to increase plant water availability, and use of rainwater to overcome erratic rainfall especially in the relatively higher rainfall areas of highland Ethiopia. There are also important other ways to reduce risk for farmers (social, economic, spatial diversity) and for the government (trade, buffer, pricing).

The estimates of the irrigation potential of Ethiopia vary from one source to the other, due to lack of standard or agreed criteria for estimating irrigation potential in the country. The earlier reports for example according to World Bank (1973) as cited in Rahmato (1999) show the irrigation potential at the lowest 1.0 and 1.5 million hectares, and the highest according to Tilahun & Paulos (2004), on the order of 4.3 million hectares. Table 1 provides the distribution according to the latter. Thus, the above variation in estimates calls for accurate review of the irrigation potential of the country.

Similarly, there is no consistent inventory with regard to the developed irrigation of the country. In 1990, BCEOM (1998) estimated a total of 161,000 ha of irrigated agriculture for the country as a whole, of which 64,000 ha was in small-scale schemes, 97,000 ha in medium and large-scale schemes, and approximately 38,000 ha as being under implementation. Tilahun & Paulos (2004) report that the traditional irrigation schemes alone cover 138,339 ha, and that 48,074 ha are under modern small scale irrigation, 61,057 ha under modern large and medium scale schemes, with the aggregated sum of irrigated agriculture at 247,470. From the latter, it can be seen that small-scale irrigation contributes 75% of the irrigation (74.2% traditional and 25.8% modern small scale). Given the current household level irrigation expansion[E1] through traditional schemes and water harvesting, it is also possible that the total sum of actual irrigation development could be over 250,000 ha. One of the limiting factors of irrigation potential is water abstraction. The Ethiopian hydrographical network often shows deep and narrow gorges that make water abstraction costs extremely high. However, construction of multipurpose dams for irrigation, hydropower and flood control may help reduce the per hectare cost of development.

Ethiopia indeed has significant irrigation potential assessed both from available land and water resources potential. Irrespective of the lack of knowing what is the accurate potential and what has been developed, and despite efforts of the government to expand irrigation specially on SSI, MI and RWH, the country has not achieved sufficient irrigated agriculture to overcome the problems of food insecurity and extreme rural poverty, as well as to create economic dynamism in the country.

Large and Medium Scale Irrigation

Irrigation projects in Ethiopia are identified as large-scale irrigation if the size of command area is greater than 3,000 ha, medium scale if it falls in the range of 200 to 3,000 ha, and small scale if it is covering less than 200ha. The categorization in this document is based on the size of land irrigated. In addition to the above classification according to MOWR (2002), the new classification developed by Lempérière also includes the dimensions of time and management. This system distinguishes between four different types of irrigation schemes in Ethiopia: traditional, modern communal, modern private and public. More details on the different types can be found in Werfring *et al.* (2004: in press). The existing irrigation scheme development based on Regions and River Basins is shown in Table 1.

Although the number of large and medium scale irrigation projects has remained stagnant in the last decade, in the new water sector development program, these types of irrigation schemes are considered important. Figure 1 provides information on the targeted development of irrigation schemes in Ethiopia. The development of large-scale schemes is useful as they are[E2] associated to useful infrastructure development, create job opportunities, and contribute to agricultural growth and to the macro economy.

Table 1: Existing Irrigation Schemes by Region (Source: Tilahun & Paulos, 2004).

S. No.	Region	Irrigable Potential	Current Irrigation Activities		
			Traditional	Modern Irrigation	
				Small	Medium & Large
1	Oromia	1,350,000	56,807	17,690	31,981
2	Amhara	500,000	64,035	5,752	-
3	SNNP	700,000	2,000	11,577	6,076
4	Tigray	300,000	2,607	10,000	-
5	Afar	163,554	2,440	-	21,000
6	Ben Shangul Gumz	121,177	400	200	-
7	Gambella	600,000	46	70	-
8	Somali	500,000	8,200	1,800	2,000
9	Hareri	19,200	812	125	-
10	Dire Dawa	2,000	640	860	-
11	Addis Ababa	526	352	-	-
TOTAL		**4,256,457**	**138,339**	**48,074**	**61,057**

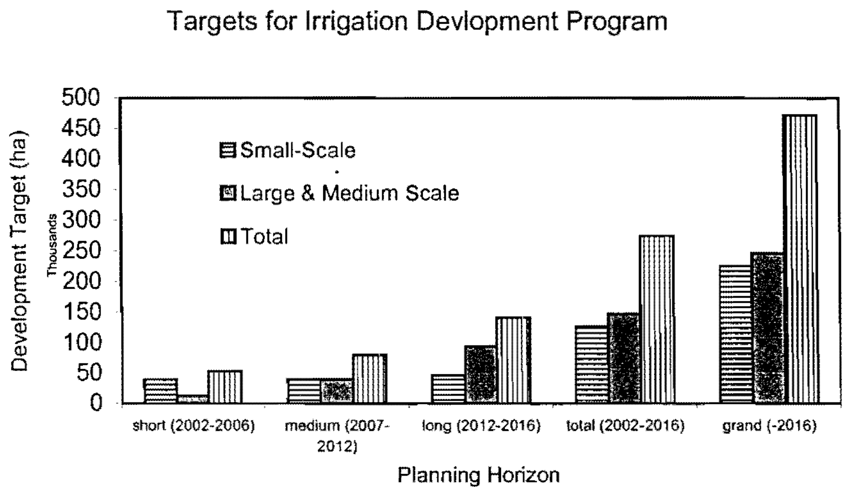

Figure 1: Irrigation Development Targets (data based on MoWR, 2002)[2].

Parallel to the water sector development program, there are considerable efforts to develop master plans for the various river basins such as Abay, Tekeze, Wabishebelle. In fact comprehensive master plans for five basins are already developed. Through these master plan studies, a number of medium and large-scale irrigation projects are identified. The challenge is to transform these master plans into practice through undertaking feasibility studies, design and construction, operation and maintenance in a sustainable and profitable way.

Even with its limited capital for investment, Ethiopia needs to consider the opportunities that large and medium scale schemes provide as mechanisms of food security and fighting poverty. Many countries have developed irrigation schemes as public investment (e.g., India, China, Egypt, USA) and some are still developing irrigation through the allocation of public and government resources (e.g., Turkey, Brazil). Though not always designed as pro-poor

[2] *Note that grand is total existing plus the planned schemes.*

interventions, large-scale irrigation schemes in Asia have been shown to have positive poverty impacts (Hussain, 2004). The Government could also consider other models found in for example China and build large public schemes at its expense, and then contract out the operation and maintenance (O&M) and even agricultural services to private firms; and promote farmer-based WUAs or coops at secondary canal levels to do the O&M at that level.

Small Scale Irrigation Schemes

The small-scale irrigation schemes in Ethiopia are understood to include traditional small scale up to 100 ha and modern communal schemes up to 200 ha (MoWR 2002). However, we also see a 'traditional' *spate* irrigation scheme in, for instance Tigray, of up to 400 ha. Traditionally farmers have built small-scale schemes on their own initiative, sometimes with government technical and material support. They manage them through their own users' association or committees (MoWR 2002). The farm size varies between 0.25 ha and 0.5 ha. Water user associations have long existed to manage traditional schemes. They are generally well organized and effectively operated by farmers who know each other and are committed to cooperating closely to achieve common goals. Typical associations comprise up to 200 users who share a main canal or a branch canal. They may be grouped into several teams of 20 to 30 farmers each. Such associations handle construction, water allocation, operation and maintenance functions.

The Federal or Regional Government normally constructs small-scale modern schemes. Such schemes have been expanded after the catastrophic drought in 1973 to achieve food security and better peasants' livelihoods by producing cash crops. Such schemes involve dams and the diversion of streams and rivers. The constructed and completed schemes of such types are usually "handed over" to WUAs for management, operation and maintenance with the support of personnel from Regional Bureaus. See section 4 for further discussion.

Micro Irrigation

Micro irrigation is not understood in the same sense in all regions of Ethiopia. Sometimes the term is used for small-sized schemes of less than 1 hectare developed at household level, such as rainwater harvesting schemes. Others consider micro irrigation in relation to the technology and refer to drip irrigation schemes. In this report, we use "micro irrigation" to refer to individualized small-scale technologies for lifting, conveying and applying irrigation water. It therefore includes treadle and small power pumps to lift water, and a variety of irrigation application technologies such as small bucket and drip systems, and small sprinkler systems. In general, the advantages of this category of technologies are: 1) they can be adopted and used by individual farmers, i.e., are not depending on collective action by groups; 2) they are of relatively low cost in terms of their capital and operating costs (per farm, not necessarily per hectare) and therefore are potentially affordable by small farmers; 3) they are often highly efficient in use of water (high water productivity) while also improving crop quality and reducing labor costs; and 4) they can be distributed by private firms through markets, i.e., are not dependent on being provided by government institutions. This category is sometimes referred to as "Affordable Micro Irrigation Technology, AMIT" (ITC et al., 2003) to distinguish it from commercially available 'high-tech' irrigation application technologies such as pressurized drip systems.

In Ethiopia, some private entrepreneurs producing high value crops are using the latter types of conventional 'high-tech' micro irrigation systems. All of the mushrooming flower farms (around Sebeta Hollota areas in the Oromia Region) and to some extent others such as vegetable farms (e.g., Genesis Farm in Debre Zeit, Oromia Region) are using these conventional imported irrigation technologies on relatively large holdings.

The use of micro irrigation, for example under current efforts of water harvesting in Ethiopia where the harvested volume of water is small, is appropriate from the point of view of conserving water.[E3] The use of micro irrigation by poor farmers has hardly begun in

Ethiopia. Its introduction is a recent phenomenon, with some attempts to utilize this concept by NGOs (such as World Vision in the South, SNV in Wello Area) and universities such as Arba Minch University (AMU) and Mekelle University (MU)[E4].

It is appropriate and timely to consider introducing the wide range of technologies developed elsewhere such as in India and Kenya, so farmers can make their own selection. For example, farmers in India in 2002 could buy four types of kits: bucket kit, drum kit, customized kit and micro sprinkler. According to ITC et al. (2003), the prices of different types of kits ranged from Rs 225 (US $5) for bucket kits to Rs 3,000 (US $63) for tank kits. Individual farmers directly purchase these kits.

In Ethiopia there are also local manufacturers such as Selam and Wolita Rural Development Center that are trying to manufacture and promote treadle pumps. Treadle pumps and small power pumps could provide an opportunity to lift water stored from harvested rain in underground tanks or shallow ground water wells. This type of technology could be also imported[E5] and adapted for up scaling.

It should be understood that adding 'only' water to the soil increases the rate with which the crop removes plant nutrients, and when these are not replenished by chemical or organic fertilizer, the soil degrades, reducing production capacity even faster than if no water were added. In other words, a plant nutrient replacement strategy must be part of any irrigation strategy. Market-driven profitable agriculture provides farmers incentives to invest in soil fertility.

Rainwater Harvesting

The term rainwater harvesting (RWH) is used in different ways and thus no universal classification has been adopted (Ngigi, 2003). According to Critchley and Siegert (1991), water harvesting in its broadest sense is defined as the "collection of runoff for its productive use." Runoff may be harvested from roofs and ground surfaces as well as from intermittent or ephemeral watercourses. A wide variety of water harvesting techniques for many different applications is known. Productive uses include the provision of domestic and livestock[E6] water, concentration of runoff for crops, fodder and tree production and less frequently water supply for fish and duck ponds.

An excellent overview on land and water conservation technologies and small to medium scale irrigation in Ethiopia is presented by WOCAT (http://www.fao.org/ag/agl/agll/wocat/wocatqt.asp). It lists 7 technologies specific for Ethiopia, while many others from other countries apply in some areas. Oweis et al. (1999) reviewed water harvesting methods used in winter rainfall areas (>100 mm per year) and in summer rainfall areas (>250 mm). They give an excellent overview of the theory of catching, concentrating and storing of water, and how this relates to rainfall characteristics, landscape and crop demands. The principles have been known and applied for millennia. Practical designs are given, yet the authors note that recent attempts to encourage more farmers in semi-arid zones are often disappointing, and give the following reasons: (i) people often do not understand the principles and get inadequate training, (ii) transaction costs are high, (iii) outside institutions are often needed to get started, (iv) too little focus on 'risk' and how to handle it, and (v) cooperation with different people (i.e., not worked with before) is difficult. The fact that many farmers in semi-arid regions do not own the land they farm is another reason why investments in water harvesting are low. Not mentioned in the review but likely also a cause of slow uptake is that many of the farmers in semi-arid regions have more experience of being a herdsman than being a cultivator. Kunze (2000) showed that although profitability of water harvesting can be significant at the field level, it might still be negligible if only applied to a small part of the farm.

RWH systems are generally categorized into two categories: a) *in-situ* water conservation practices, small basins, pits, bunds/ridges, and b) runoff based systems (catchment and/or storage). The storage system is usually used in supplemental irrigation. The *in-situ* systems, which enhance soil infiltration and water holding capacity, have dominated over storage schemes in Ethiopia until recently. Despite the additional costs involved in storage schemes, the recent trend shows there is a relatively high degree of adoption. Surface runoff from small catchments and roadside ditches is collected and stored in farm ponds holding an average of about 60m^3 of water. This storage is not significant in volume and thus is usually used for supplementary irrigation of vegetables. The use of these systems can be extended to crop fields and larger plot sizes can be warranted through larger sizes of storage combined with efficient water application methods such as low-pressure drip irrigation methods.

Hence, rainwater harvesting is a useful mechanism to overcome the recurrent erratic rainfall and dry spell conditions which often result in crop failures in Ethiopia. There is a need to effectively promote promising RWH technologies and systems; to incorporate and integrate land users' knowledge and innovations; and to build capacity of the land-users to assimilate, adopt and adapt various technologies. We address this in the following sections.

Main Gaps to promote SSI, MI and RWH in Ethiopia

The following lists are key constraints, knowledge gaps and broad research needs in effectively implementing the technologies of small scale irrigation, micro irrigation and rain water harvesting in Ethiopia (for details, see IWMI 2004):

Main Constraints

- Lack of or inadequacy of baseline studies, data and information on potentials of different areas for the development of water resources
- Poor technology choice
- Low yields
- Property rights
- Too small landholdings
- Conflicts in water use and use rights
- Marketing and market access
- Dependency syndrome
- Institutional arrangements and instability
- Lack of training to handle technologies; lack of extension services
- Lack of start-up capital or access to credit to initiate venture
- Poor linkage between research and extension in the area of irrigation water management

Main knowledge gaps

- Faulty design
- Lack of knowledge on use of modern irrigation technology
- Poor water management
- Poor land management
- Poor input utilization
- Poor management capacity
- Lack of information and database
- Lack of post-harvest technology and management

Future Opportunities

- High water potential
- High commitment of the Ethiopia government, donors and NGOs to support irrigation management and development activity

- Opportunity for implementing multiple use water systems (MUS), with regions coordinating sub-activities. Effective utilization of scheme infrastructure through diversification of uses to meet various needs for water such as domestic, irrigation, livestock and hygiene is the most important.
- Opportunities for improving knowledge of policy makers, planners, designers, contractors and development agencies through education, training, dialogues and participation
- Opportunities for more gender-equitable investments, targeting poor women, through for example MUS and micro irrigation

Research Needs
These research needs specific to this paper can be grouped into the following broad categories:

- *Policy research* – strategic policy research to enhance the improvement of national level policies and processes, and to enhance the realization of broader poverty and food security impacts of smallholder irrigation interventions at national, regional and local (community and household) levels.
- *Socio-economic and market research* – research on marketing and market information so that farmers can produce targeted crops using irrigation was a general issue in all regions; market surveys and analysis so that farmers can produce according to market requirements; input supply arrangements during irrigation period; research on how to successfully upgrade traditional schemes into modern ones, including organizational issues related to WUA formation; benefit-cost analysis for alternative irrigation technologies taking into account affordability, accessibility, maintenance and sustainability.
- *Institutional research – research to establish clear and effective policies to minimize conflicts between upstream and downstream water users (raised as an issue in Amhara); problems of institutional arrangements in regional structures was acknowledged as relevant in all regions except Oromia; research on property rights regarding access to land and water was emphasized, particularly clear definition of rights to water to minimize conflicts between traditional irrigator and those on modern small scale scales.*

Conclusion

Promotion of water related technologies in Ethiopia, at small and large scales, makes good sense for a number of reasons, and there are basically good opportunities for both. Large scale irrigation schemes and technologies are relatively well known and the government has already plans to promote these systems actively. Some types of small scale technologies, especially micro irrigation technologies, however, are still relatively new in Ethiopia. Yet they have the potential of enabling supplementary irrigation for millions of people and to achieve household food security through home garden micro irrigation, and modest wealth for emerging commercial farmers. The relatively simple equipment needed can be produced locally, hence promoting off farm employment, and better post harvest stimulate the same indirect benefits. Since small scale technologies are also particularly effective in expanding the source of domestic water and for home gardens; therefore they are a key to empowering women. There are examples of successful financing mechanisms for poor farmers to adopt small scale technologies, including self financing and micro-loans.
To carry out such a program, activities must build on the ongoing projects by GOs, NGOs, CBOs and farmer organizations, and on their experiences. This includes learning from other counties, building research and extension capacity in Ethiopia, participatory implementation of household and communal water use systems for domestic and productive uses, and refining the methods for implementation through evaluation, demonstration and learning sites. It must also include development of the legal framework for land and water and related service providers. Research needs to accompany the implementation process to allow

acceleration of up- and out-scaling, and to continually adjust recommendations to local conditions and to development in materials and knowledge. To prepare for such an expansion, capacity building and awareness promotion must be addressed from the beginning. If the implementation program is successful, significant local demand for small-scale equipment will develop. The creation of local supply chains of these equipments and other agricultural inputs, including fertilizers, is crucial.
If the implementation project is really successful, significantly larger volumes of vegetables and other food items will be produced. Markets for these products need to be identified, and producers should be connected to them. These explorations should be initiated in an early stage.

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