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Full Length Research Paper

Integrated rainwater management strategies in the Blue Nile Basin of the Ethiopian highlands

Birhanu Zemadim[1]*, Matthew McCartney[1], Bharat Sharma[2] and Abeyou Wale[3]

[1]International Water Management Institute (IWMI), East Africa and Nile Basin Office, Addis Ababa, Ethiopia.
[2]IWMI, New Delhi, India.
[3]School of Civil and Water Resources Engineering, Bahir Dar University, Ethiopia.

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This paper describes one component of the research that International Water Management Institute (IWMI) and partners are undertaking as part of the challenge program on water and food (CPWF) Nile Basin Development Challenge (NBDC). The objective of the NBDC is to increase understanding of how to plan successful rainwater management strategies (RMS) and identify how these can be effectively implemented in the Ethiopian highlands of the Blue Nile Basin. The project focuses on integrated rainwater management strategies – technologies, institutions and policies but the work described in this paper relates solely to the biophysical components of the study. Three districts, Jeldu, Fogera and Diga, have been identified for the study. These were selected because they represent farming systems that are common in the Ethiopian Highlands. Within each, nested sites have been identified for learning and research at a variety of physical scales. In this paper we describe the "action research catchments" that have been identified in the three districts. These catchments are small representative catchments that are to be monitored to provide insights into hydrological processes and water fluxes at different scales. The objective of this monitoring is to provide baseline data for evaluating RMS, and water-use and water productivity in different landscape components. The baseline status of the three study sites and critical constraints for adoption of integrated RMS are included in this paper. The paper also provides a justification for the research being conducted in Ethiopia and describes common practices and lessons learned from experience in India. Differences in the socio-economic and biophysical context mean that care is needed in transferring approaches between countries. Nevertheless, it is believed that knowledge gained from the extensive Indian experience can usefully inform practices in Ethiopia.

Key words: Blue Nile Basin, Diga District, Ethiopian highlands, Fogera District, Jeldu District, rainwater management, watershed development program.

INTRODUCTION

The Ethiopian highlands extend from 1500 to 4,260 masl, with an average slope of greater than 25 percent in the eastern part (Yilma and Awlachew, 2009). The highlands in the Blue Nile basin are characterized by rainfall of between 900 and 2500 mm. However, this relatively high rainfall is not easily retained. The frequent occurrence of intense precipitation in the highlands reduces infiltration and causes much of the water to immediately become runoff. It is the inability to predict and manage rainfall, and consequent runoff, variability which is a key contributor to the high levels of food insecurity and poverty in the Ethiopian Highlands. The landscapes in the highlands are ecologically fragile and poverty and marginalization are typical characteristics of the rural villagers living in the areas. Poor land management practices and ineffective rainwater management strategies (RMS) exacerbate the situation. A recent report, the Ethiopian strategic investment framework for

*Corresponding author. E-mail: b.zemadim@cgiar.org, birhanuzem@yahoo.com. Tel: +251 11 6457222/3. Ext (2200 or 2192). Fax: +251 11 6172001.

sustainable land management (ESIF-SLM, 2010), reported that the highlands of Ethiopia have enormous agricultural and natural resources potential. However, the lack of land management programs in the past have resulted in improper land use and severe consequences for livelihoods. Similarly, the Ethiopian Reporter (a bi-weekly newspaper) reported that rain water harvesting (RWH) and its utilization has been ranked as poor in six regional states of Ethiopia. The report referred to the diagnostic research conducted by the Ethiopian RWH association and cited major problems as: (i) the structures constructed to harvest rainwater were not built to the required standard and cannot contain enough water; (ii) there was no close supervision of the structures; (iii) the approaches lack community cooperation, (iv) most structures were built rapidly with poor planning and lack of decentralized ownership systems (Reporter, 2010). The result of poor planning and construction of such structures is hardship and insecurity. Rather than bringing benefits, the vicious cycle of poverty is aggravated. For poor communities living on fragile and degraded hillsides actions must address the deteriorating environmental conditions that undermine their livelihoods and their capacity to cope with disasters (WRI Report, 2003).

With limited resources and access to external services communities in the Ethiopian Highlands are unable to safeguard their livelihood systems. Improving the resilience of these communities is of utmost importance and requires a focus on issues of land degradation and water scarcity. This is because land degradation and water scarcity are the most intense and common problems of many rural Ethiopians living in highland areas. Land degradation, for example, has been identified as a contributing factor to low /poor agricultural productivity. Overall, the annual costs of land degradation in Ethiopia are estimated to be at least 2 to 3% of agricultural gross domestic product (ESIF-SLM, 2010). The land degradation and associated water scarcity are multi-dimensional problems, which the piecemeal efforts of different agencies have failed to tackle effectively in the past (ESIF-SLM, 2010). Thus the major goal of RMS should be to contribute to poverty reduction and improve the quality of life of the rural communities. Effective rainwater water harvesting (RWH) in highland catchments should be based on natural resource regeneration and management. Restoration of the local environment through RWH is possible only if there is a focus on the entire watershed and integrated community-led approaches are adopted. Hence, all environmental regeneration and management programs should have an environmental unit for planning and implementation.

The NBDC focuses on a watershed approach towards RMS. Biophysical research, which will complement social economic evaluations being conducted, is being undertaken in three small action research catchments in three districts in the Blue Nile basin of Ethiopia. The districts are: (i) Fogera in North-Western Ethiopia (a relatively high potential, market-oriented, rice–based system); (ii) Jeldu in central Ethiopia (a relatively low-potential system with steep agro-ecological gradients) and (iii) Diga in Western Ethiopia (a relatively high potential system with poor market access but with high value crops and livestock potential) (CPWF E-Letter, 2010). The action research catchments within these districts are being used to gain understanding of hydrological processes and water fluxes at different scales, which in turn will be used to provide baseline information for evaluating different RMS options.

EXISTING RAINWATER MANAGEMENT (RWM) PRACTICES IN ETHIOPIA

Both traditional RWH techniques (such as runoff farming) and *in-situ* water harvesting techniques (such as micro-basins) are used in Ethiopia (Johnston and McCartney, 2010). A recent study (AMU, 2009) revealed that of 40,000 RWH ponds constructed between 2003 and 2008 in the Amhara and Tigray regions of Ethiopia, most have failed. *In-situ* water harvesting structures are made from plastic PVC, sheet metal and reinforced concrete and are put above and below the ground surface. However, most of these structures were found not to be complete in their construction and lack close monitoring after their construction, and hence cannot store water effectively during rainy season (Reporter, 2010).

Runoff farming practices which are closely related to the soil water conservation (SWC) program date back to 1970 in Ethiopia. The aim of this program is to reduce soil erosion and has little interest in enhancing soil water infiltration *per se*. With slow uptake by local farmers, the program faces a lot of challenges. Farmers state that in the past their participation was forced by agricultural extension officers rather than self-motivated. What also makes SWC programs unsuccessful in Ethiopia is that the technologies are rarely sufficiently adapted to local conditions (Bewket and Sterk, 2002; Amsale and de Graaff, 2007). In conjunction with SWC programs, measures like protecting forested areas and reducing soil erosion by building terraces and planting tree seedlings have been ongoing since the mid-1970s, but also with limited success (Bishaw, 2001). Despite many failures, however, there are a few successful stories of RWM programs as part of the sustainable land management (SLM) project being conducted by the Ministry of Agriculture and Rural Development (MoARD). The projects that are showcased in Amhara, Oromiya, Tigray and Somali region include various technologies and approaches to increase *in-situ* water availability and increase aquifer recharge. These are described in detail in practical applications through watershed development.
However, those technologies and approaches that are deemed successful by the MoARD have not been

Table 1. Selected study landscapes.

Landscape	District	Predominant farming systems	Mean annual rainfall (mm)
Diga/ Dapo watershed	Diga	In the lowland maize is the dominant crop followed by sorghum, millet and sesame and perennial crops coffee and mango. In the midland, teff, millet and maize are important in that order. Livestock keeping is common all over, therefore, the farming system is: “Mixed crop-livestock system”	1,376 to 2,037
Fogera/ Mizewa watershed	Fogera	Rice is the major crop followed by maize, millet and tef, barley and ground nut. Farming system is: “Mixed crop-livestock system”	974 to 1,516
Jeldu/ Meja watershed	Jeldu	Potato, barley, wheat, faba bean and F.pea are the dominant crops in the highland area, but maize, sorghum and tef are common from mid to lowland. Except in upstream area crop rotation is largely replacing the fallowing practices due to shrinkage of the size of land possessed by individual farmers. : “Mixed crop-livestock is the common farming system”	900 to 1,350

properly documented and reported (SLMP, 2010). Hence scaling up of best SLM practices and identification of appropriate types of technology for water storage options in specific situations remains a challenging problem in Ethiopia (SLMP, 2010; Johnston and McCartney, 2010).

RESEARCH SITES

The NBDC research is being conducted in areas (called “study landscapes”) representing dominant agro-ecological zones and farming systems. Three study landscapes (Table 1) within the three districts were selected as a nested set of sites for learning and research at a variety of physical and social scales (Figure 1). Within each study landscape, “action research catchments” were identified as follows:

(i) Dapo watershed (18 km^2) in Diga District,
(ii) Mizewa watershed (27 km^2) in Fogera District and
(iii) Meja watershed (93 km^2) in Jeldu District.

In each of the action research catchments the intention is to install hydro-meteorological instruments (comprising flow, rainfall, weather, and soil moisture and groundwater measurements) to provide insights into hydrological processes and water fluxes at different scales. The objective of this monitoring is to provide biophysical information that can be used to evaluate the impacts of RMS on hydrological flows as well as to determine water-use and water productivity in different landscape components. Data obtained will be used in conjunction with computer models (e.g. SWAT and WEAP) to evaluate the possible implications (including downstream impacts) of scaling up interventions. Data will be collected for two-years (that is, 2011-2012).

HYDROLOGICAL CHARACTERISTICS OF THE STUDY LANDSCAPES

The Abbay basin (199, 812 km^2), where the three research sites are located, accounts for a major share of Ethiopia’s irrigation and hydropower potential. Average annual run-off at the border with Sudan is estimated to be 54.8 Bm^3 and irrigation and hydropower potential are estimated to be 815,581 ha and 78,820 GWhy^{-1} respectively (Awlachew et al., 2007). The total population in Abbay basin is 27 million (CSA, 2008) and thus the per capita water availability is 2,029 m^3 per year, which exceeds the national average of 1,707 m^3 per capita per year (Awlachew et al., 2005). Hence, a relatively large volume of water is available in the Abbay basin. However, these average annual figures disguise considerable spatial and temporal variability which means that due to lack of water storage there is not enough water for most farmers to produce more than one crop per year.

It is important to have hydro-meteorological monitoring stations to study the whole range of hydrology in the basin. However, currently the number of monitoring stations is very limited and there are no stations within the three action research sites: these will be installed as part of this project. To give some idea of the natural variability in flow and rainfall, data have been collected from monitoring stations located in the Fogera District, close to, but not in, the Mizewa catchment (Figure 2).

Four rainfall stations at Addis Zemen, Infranz, Bahir Dar and Debre Tabor are located within or near Fogera District and close to the Mizewa watershed (Figure 2). The long term (1992 to 2003) seasonal monthly precipitation is presented in Figure 3. As shown in Figure 3 there is a uni-modal rainfall and the twelve years of rainfall data indicate that in each of the six months (May to October) average rainfall record is greater than 50 mm. In Fogera District flow gauging stations are installed at two watershed outlets (the Ribb and Gumara Rivers) (Figure 2) and are reasonably close to the Mizewa watershed. The seasonal distributions of flow at these stations indicates that the flow distribution closely follows rainfall pattern with peaks recorded in July and August (Figure 4). The flows at the outlet of both Ribb and Gumara shows a similar runoff pattern with a coefficient of determination, R^2 = 98% on a long-term monthly basis for the study period (1992 to 2003).

The long-term average monthly discharge is maximum in August and minimum around March and April for both rivers. The long-term average annual runoff is 1330 and 511 Mm^3 for the Gumara and Ribb watersheds respectively for the period 1992 to 2003. The population density in Ribb and Gumara watersheds ranges from 225 to 250 persons per km^2 (Yilma and Awlachew, 2009). The total watershed area of both watersheds is 2986 km^2 and hence with a total flow volume draining from both catchments, which is 1841 Mm^3, the average per capita water availability is 2595 m^3 per year. This figure is higher than both the national figure (1707 m^3) and basin figure (2029 m^3). It indicates that the Fogera District is not a water scarce region and abundant water is available. However, this

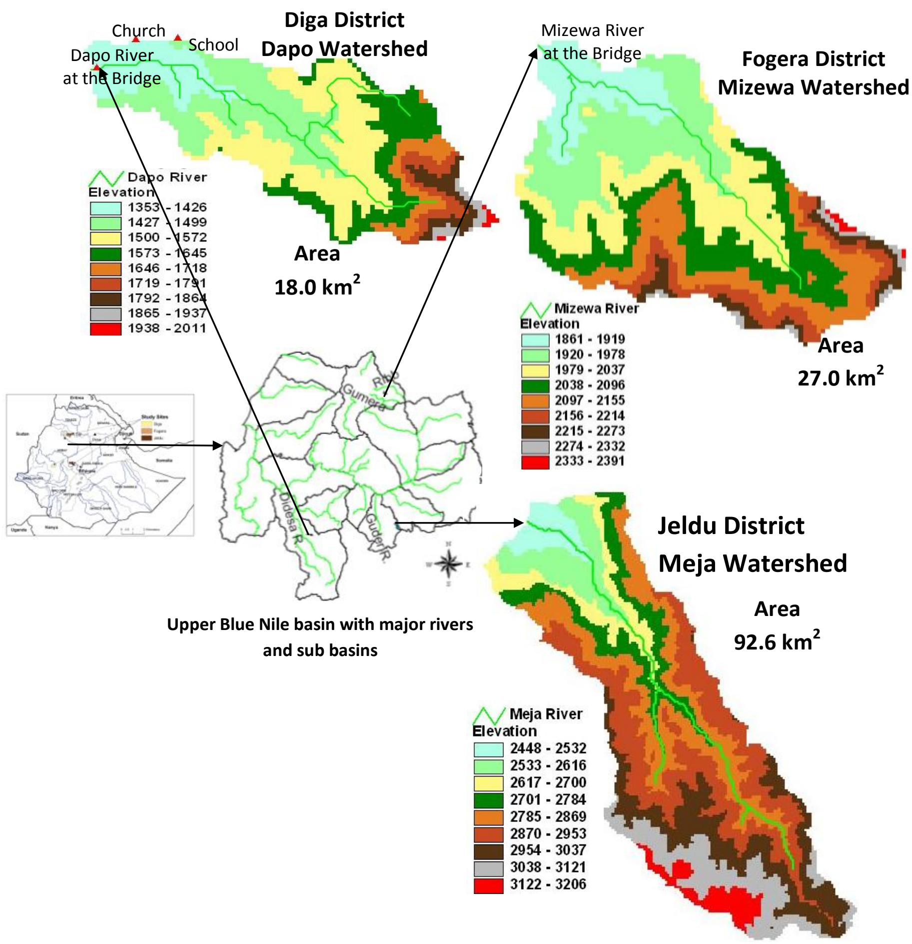

Figure 1. Location of research sites.

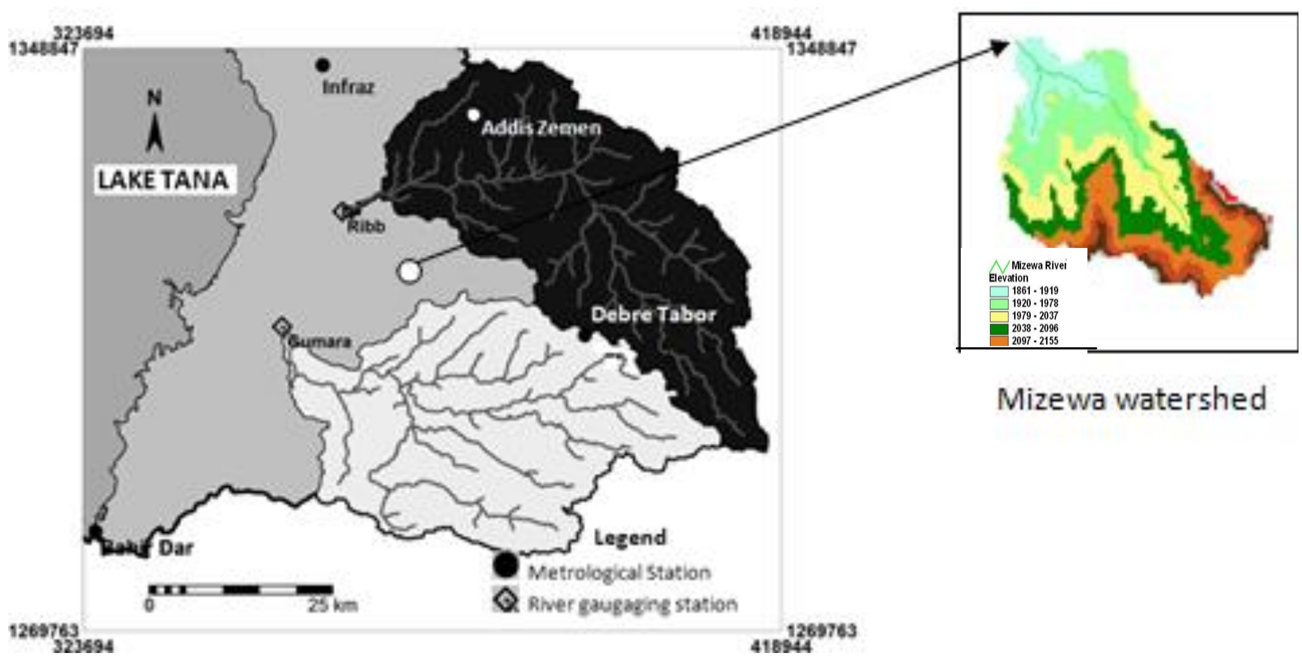

Figure 2**.** Location of hydro-meteorological stations and Ribb and Gumara watersheds.

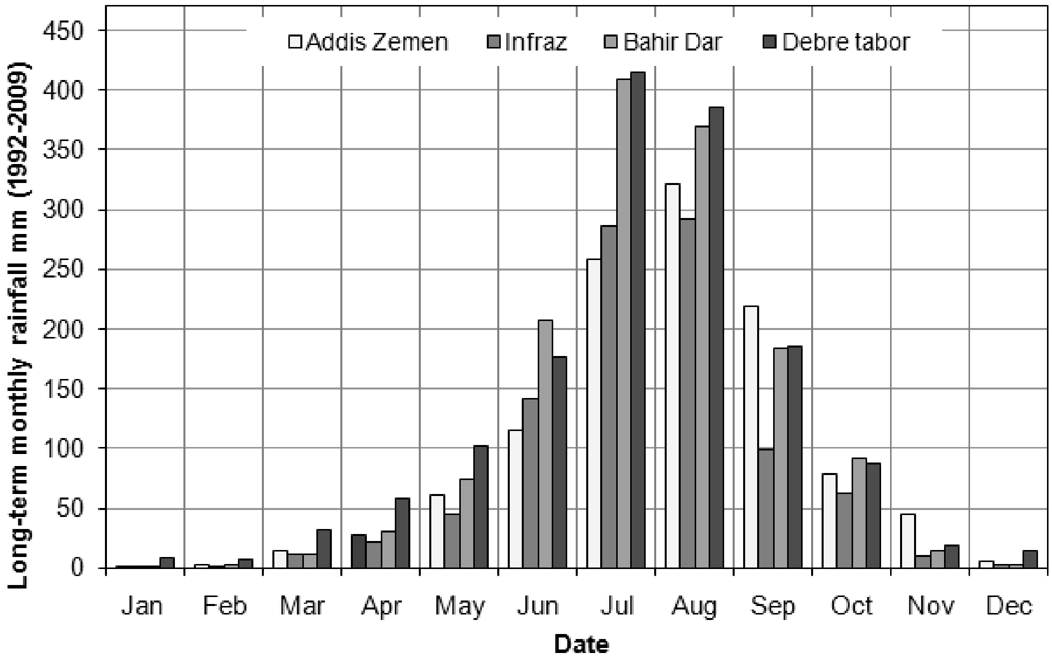

Figure 3. Long term average precipitation for stations nearby Fogera District (1992 – 2003).

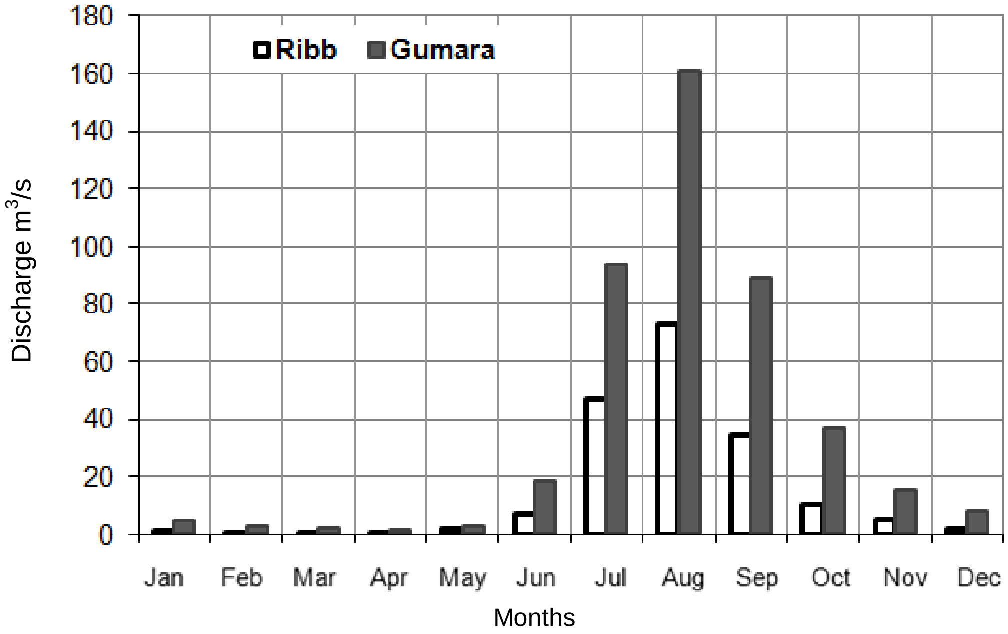

Figure 4. Seasonal distribution of flow at the outlet of Gumara and Ribb watershed (1992-2003).

resource has not been tapped properly and heavy floods in the rainy season are typically followed by water shortages during the dry season. Much of the available water in the area remains unutilized due to absence of proper storage and water resources planning. Improved rainwater and watershed management could contribute significantly to the wellbeing and livelihoods of the local population.

PHYSICAL DESCRIPTION OF STUDY LANDSCAPES

Diga area

The Diga area, located in the south-west of the Abbay basin is bordered in the north east by Guto Gida District (Nekemt town), which is the zonal capital of east Wollega, and in the west by the

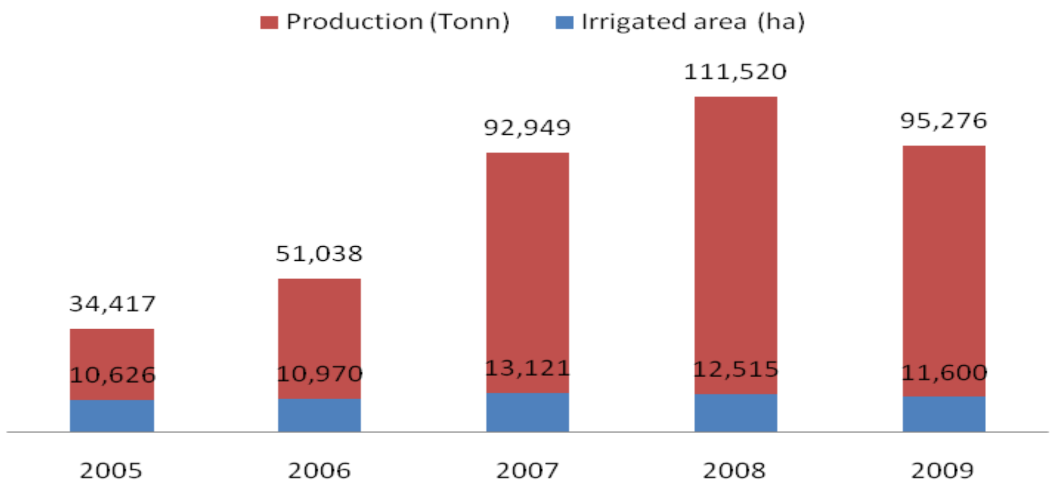

Figure 5. Irrigation statistics and productivity in Fogera District. (Source: Woreta Agricultural and Rural Developemnt Bureau).

a b

Plate 1. (a) Deforestation in midlands of Diga area and (b) Lowland of Diga area.

Photo credit: Birhanu Zemadim, 2010

Didessa River, one of the major tributaries to Blue Nile River, on the north by Sasiga District and on the south and southeast by Jimma Arjo and Leka-Dulecha Districts. The area is one of the highest rainfall regions of the Ethiopian highlands. In some places mean annual rainfall exceeds 2,000 mm. The altitude in the area varies from 1,200 to 2,342 masl and comprises two agro-ecological zones: the lowlands and midlands (Figure 1 and Table 1). The midlands are steep, formerly forested terrain which is being rapidly cleared of trees. Large areas of forest have been cleared in the last 10 years (Plate 1a). Scattered communities tend to cultivate the tops and bottoms of slopes because the slopes themselves are steep. However, there is increasing cultivation of the slopes and hence increasing problems of soil erosion and loss of soil fertility. In some places all the top soil (sandy clay loams and sandy clay) has been lost. Once the productivity declines too far, farmers simply move on, clearing more forest. The lowland, bordering the Didessa River, is less steep than the midlands, comprising more rolling terrain and in recent years there has been a large influx of people into this lowland area (Plate 1b).

Most rivers in the district are perennial but in recent years scarcity of water during the dry season for livestock and people has become an increasingly common phenomenon. Local experts attribute the water scarcity to: (i) population pressure; (ii) lack of soil conservation measure to reduce erosion;(iii) deforestation; and (iv) overgrazing. There is a lot of potential for irrigation, particularly on the flatter terrain of the lowlands. At least 7 of the 31 rivers in the district have the potential to irrigate 300 ha each (that is, a total of 21,000 ha). In the last season 1,769 ha has been used/developed for traditional irrigation. Some farmers now have diesel pumps through a government scheme which distributed some 21 pumps. It is possible that up to 330 ha are irrigated with pumps. On irrigated land farmers can grow 2 to 3 crops per year. In some places, *Bone*, a traditional practice of cultivating in wetland areas using residual moisture, is being undertaken. It is estimated that this is practiced on 1,879 ha in the Diga Woreda. Some farmers have built small ponds and reservoirs, but currently there is seemingly little real

a b

Plate 2. (a) Rice grown on the Fogera plains and (b) Waterlogged maize (Photo Credit: Matthew McCartney, 2010).

a b

Plate 3. (a) Midlands in the Fogera Woreda and (b) Rainwater harvesting pond (Photo Credit: Matthew McCartney, 2010).

enthusiasm in RWH practices.

Fogera area

The Fogera area, located in the north-east of the Abbay basin, to the east of Lake Tana (Figure 1) comprises a large flat floodplain in the vicinity of the lake and contributing hilly catchments to the east. The altitude varies from 1,784 to 3,600 masl. Rainfall varies from approximately 1,000 mm on the plains to about 1,500 mm at higher altitudes. In Fogera Woreda 77 perennial and 38 intermittent rivers are recognized. There are also 155 springs that are used for domestic water supply and irrigation. According to the district agriculture office there are a total of 820 pumps.

The Fogera plains are extensively cultivated with large areas of rice (Plate 2a) and vegetables (e.g. onion and maize). This area has been converted from grazing to rice in the last 5 years. Farmers utilize traditional diversions and increasingly small pumps for irrigation. The water table is shallow; typically 2 to 4 m and some farmers have wells. However, the wells cannot be dug too deep as they tend to collapse. Flooding is a major problem during the wet season and though this keeps the soils fertile, water logging of maize is a common problem (Plate 2b). There are lots of rivers and the water table is high. However, local farmers report that water scarcity is a major problem in the dry season because water is being diverted for upstream irrigation. In recent years dry season conflicts between upstream and downstream communities in this catchment have reached a level where the police have become involved.

In the midlands, the terrain is much steeper with rock inselbergs in some places (Plate 3a) and the water table is deeper (depth from 12 to16 m). The district agriculture office recommends the use of RWH ponds in preference to digging wells. To date 18 trapezoidal ponds lined with geo-membranes (Plate 3b) have been constructed in different kebeles of the district. Each pond can store 129 m^3 of water, sufficient to irrigate approximately 0.25 ha. The district office is planning the construction of 67 new water harvesting structures over the next year.

Information obtained from the nearby Woreta Agricultural and Rural Development Bureau, indicated that over the five years, 2005 to 2009, there was wider use of irrigation in Fogera District and increased agricultural productivity (Figure 5). The wider use of

a b

Plate 4. Meja River catchment: (a) the upper catchment – a broad valley and (b) mid-catchment - deeply incised valley. (Photo Credit: Matthew McCartney, 2010).

Plate 5. Gulleying in the catchment of the Meja River (Photo Credit: Matthew McCartney, 2010).

irrigation in the district was derived mainly because of increased demand for cash crops. Extension agents from nearby agricultural offices have also trained the local farmers on the efficient use of the available water. At times farmers consider local market demands and act accordingly, changing the crops grown. The increased cost of onion and potato in 2007, for example, caused local farmers to shift from rice and millet to onion and potato in 2008 and resulted in increased productivity per hectare (Figure 5).

In the action research catchment, which is on the hills and not in the rice growing flood plain, various interventions have been undertaken. These include soil conservation practices: terracing, zai pits, hydrobasins afforestation and protected areas. Many of the interventions in the catchment have been undertaken on the initiative of the local communities. The communities complain of water shortages in the dry season, attributed to upstream pumping and also the plantation of eucalyptus trees. There are at least three locations within the catchment where water is pumped for irrigation. This is reportedly resulting in the dry season drying of one of the major tributaries in the catchment (that is, the Ginde Newr). The communities also complain that the RWH ponds are failing for a variety of "unforeseen" reasons.

Jeldu area

The Jeldu area, located in the south of the Abbay basin to the north-east of Ambo is predominantly a highland area. The major river draining approximately south-north is the Meja River, a tributary to Guder River. The River originates just outside Jeldu in the Ginchi District in a place locally called 'Galessa' hills. The headwaters are in a flat wide valley, which is a wetland heavily utilized for livestock grazing (Plate 4a). It then drops steeply and flows through a relatively narrow deeply incised valley. Numerous tributaries drain into the Meja from both the east and west. These are also deeply incised - mountain streams - with relatively small catchments (that is, typically 3 to 4 km^2) (Plate 4b).

Most communities live on the ridge tops but cultivate the steep valley sides. Slopes of up to 80° are being cultivated. Where slopes are too steep for tilling by oxen people use hoes. The area has been heavily deforested in the last 10 to 20 years and erosion is a major problem. Both slope slumping and gulleying are common phenomena (Plate 5). There are not many interventions as regards to soil water conservation or RMS. Farmers plant eucalyptus (currently occupying approximately 10 to 15% of the landscape) to mitigate gulley expansion and generate cash income by planting it along the gully line and on degraded areas. In the district some farmers believe productivity has "halved" in recent years. Twenty three kebeles in the district are food insecure with seasonal water scarcity. Within the action research catchment there are some traditional diversions for irrigating potatoes, maize and onions. However, water scarcity prevails during the dry season.

GUIDING PRINCIPLES TOWARDS EFFECTIVE RWM STRATEGIES: LESSONS FROM INDIA

According to a water resources research report (WRI Report, 2003) effective RMS are best achieved on a micro-catchment basis. The approach recommended emphasizes self-help, ecological regeneration and "catching rain wherever it falls". This means the full range of water storage options in catchments need to be considered – water storage in soil moisture, wetlands, water harvesting structures and groundwater (McCartney and Smakhtin, 2010; Annual Report, 2009). Recharging aquifers with rainwater that would otherwise run-off has been a very successful approach in Tamil Nadu, Maharashtra and Gujarat states of India. Similarly the World Bank supported Uttarakhand and Himachal Pradesh decentralized watershed development project helped to increase the productivity of rain-fed agriculture in ecologically fragile and erosion prone hills. The project interventions include increasing irrigated areas by 10% (about 600 ha) which has helped farmers move to high value crops, especially off-season vegetables like tomatoes, cabbage, cauliflower, peas and beans (World Bank, 2009). According to a mid-term impact survey, there has been a 10% increase in household real income (over baseline) due to the project's intervention in targeted areas.

The integrated watershed management approach has become a holistic approach for sustainable development and a corner stone of rural development in the country side (Arya and Samra, 2007; Sharma et al., 2005; Upendra, 2005). Local harvesting of a small portion of rainwater in wet periods, utilizing the same for supplemental/ protective irrigation during devastating dry spells, offers a promising solution in the fragile rainfed regions of South Asia and Africa (Sharma, 2009). Existing research and farm-level and regional development programs aimed at improvement of the watersheds have shown that proper development and use of the water harvesting systems is the first entry point for success of most of these initiatives (Joshi et al., 2005). There are however, constraints to effective watershed management approaches. Some of the challenges include local peoples participation, training programs, and institutional building, which if not given adequate attention may undermine key elements of ecological, economic and social sustainability. This means that a major dimension of appropriate watershed management is the people for whom the integrated development is expected benefit (Borthakur, 2009; Wani et al., 2009).

The issue of landed and landless should not be ignored. The study of Arya and Samra (2007) on 53 water harvesting structures in 29 villages covering 2070 families of Haryana Shivaliks in India revealed that significant benefits of integrated watershed development accrued to both the landed and the landless. Other studies in India (Arya and Samra, 1995; Kerr et al., 1998; Reddy et al., 2001) revealed that most watershed development projects favour the landed as well as those who have the wherewithal to invest in wells and pumps.

In spite of these challenges, the overall impact of watershed development has produced remarkable impacts for the livelihoods of the people of Haryana Shivaliks (Arya and Samra, 2007). Meta-analysis of 311 case studies on watershed programs in India showed that benefits of the programs were more in poor income regions as compared to higher income regions. It suggested that the watershed program would be a vehicle of development to alleviate poverty by raising farm productivity and generating employment opportunities in marginal and fragile environments. Further the benefits of watershed programs were greater where people's participation was higher and in the absence of water users' involvement, watershed programs failed to sustain themselves. The important conditions of people's participation are related to: (i) demand-driven watershed programs rather than supply-driven ones; (ii) involvement of all stakeholders (including women and landless laborers) in program implementation and monitoring; (iii) decentralization of decision making process; (iv) involvement of elected representatives of village institutions; (v) commensurate benefits of all stakeholders with their cost; and (vi) establishing effective linkages of watershed institutions with other institutions like credit sector, input delivery system, and technology transfer mechanism (Joshi et al., 2005). Earnest efforts to enthuse stakeholders for their voluntary participation would sustain watershed development and bring prosperity in the rainfed areas for which novel methods, policies and suitable forward and backward linkages need to be delivered. Some very successful model watersheds in the hilly areas include Sukhomajri, Kali Mati, Bunga, Shillong (ICAR), Fakot and Dehradun in the Himalayan states.

To overcome the challenges in RMS the WRI Report (2003) presents a series of rigorous watershed development activities that should be practiced at micro-catchment level for effective RWM programs. These are as follows:

(i) Establishing village self-help groups to help guide the watershed effort;
(ii) Building Hydraulic structures for *in-situ* water harvesting, aquifer recharge and erosion control;
(iii) Planting trees and grasses to stabilize waterways and

a b c

Plate 6. Few examples of area treatments. (a) Continuous contour trenches, (b) Stone Bunds across the slope and (c) Vegetation Bunds and plantations along CCTs (Photo Credit: Birhanu, 2010 from India). Photo credit Birhanu Zemadim, 2010 from India.

provide fodder and fuel wood;
(iv) Instituting bans on tree felling and grazing for natural regeneration of shrubs and grasses;
(v) Training villagers in new or improved agricultural practices and livelihood activities and;
(vi) Supporting cottage industries and supplemental income generation through micro-lending schemes.

PRACTICAL APPLICATIONS THROUGH WATERSHED DEVELOPMENT

A watershed is an area that harvests rainwater, stores it underground and/or channels it into a stream, a waterway and a river. In the context of RMS watershed development refers to the conservation, regeneration and judicious utilization of all the resources - land, water, vegetation, animal and human-within a particular watershed (WOTR, 2009). Apart from improving RMS, watershed development can help the communities living in the area to diversify the farming systems and improve their capacity for adapting to the impacts of climate change (WRI Report, 2003). Positive gains in the form of increased productivity, greater cropping intensity, changes in crop patterns, increased ground water recharge, reduction in runoff losses and increased employment, along with reduction in rural urban migration are testified from watershed development projects (Arya and Samra, 2007; Deshingkar, 2005; WOTR, 2009; SLMP, 2010). In the study landscapes it seems there is not much local knowledge on RWM and the involvement of non-governmental organizations is limited.

Watershed development seeks to bring about an optimal equilibrium in the eco-space between natural resources, the environment and humans. This is possible by developing micro-watersheds comprehensively so as to create sustainable livelihood opportunities for local inhabitants. The approach helps to reclaim degraded lands through the regeneration and sustainable management of watersheds and increase the use of water. The principle stated by WOTR (2009) “where the rain runs, we make it walk; where it walks, we make it crawl; where it crawls, we make it sink in to the ground” helps to reduce runoff and raise the water table. The practice is extremely important for agriculture, growth of forage and supplies of water for rain-fed cultivation.

Treatments for watershed development to conserve rainwater

In order to conserve rainwater *in-situ* and enhance soil fertility and aquifer recharge, there are three basic operations: area treatments, drainage line treatments and afforestation and pasture development. These operations need to be conducted from ridge to valley at a catchment level as presented thus.

Area treatments

Area treatments refer to practices that are made in the watershed to incrementally slow down fast flowing water until some of it stops flowing. These include construction of Continuous Contour Trenches (CCT) or hillside terraces, stone bunds, soil bunds and contour vegetation strips (Plate 6). These practice result in control of soil erosion, retention of soil fertility, improved soil moisture regimes, infiltration and groundwater recharge. The stone bunds or stone faced trench bunds technology, for example, is widely adopted by many farmers in Ethiopia to retain rainwater and reduce runoff that causes erosion. The technology is essentially a water harvesting practice intended to store rainwater for crop production and enhance ground water recharge. The technology has its origin in India and has been practiced in the Blue Nile basin, the Tigray region, North Shoa and the Awash basin of Ethiopia (SLMP, 2010).

a

b

c

d

Plate 7. Few examples of drainage line treatments. (a) Gully plugs along drainage line, (b) Nala Bunds along drainage line, (c) Check dam along the drainage line and (d) Percolation tank along the drainage line. Photo credit: Birhanu (2010) from India. Photo credit Birhanu Zemadim, 2010 from India.

Area treatments and other biophysical measures (eg. cutoff drains) that are integrated with area enclosures are common practices in the southern parts of Ethiopia. For example, in Alaba District they have been used to help maintain the productivity of degraded land which had been abandoned. Through this technology, unproductive and waste lands are changed to productive land by the prevention and reduction of erosion and enhance land rehabilitation (SLMP, 2010). Vegetated Fanya juu, that is the construction of soil embankment along the contour stabilized with biological measures such as grass, fodder trees and shrubs, fruit trees and cereals of high economic value are a RWH technology practiced in Omo-Sheleko of Southern Ethiopia. The technology provides multiple benefits; controlling runoff velocity and soil erosion, reducing the steepness of slopes, recharging groundwater, retaining soil moisture and increasing land productivity. The technology is most effective in gentle and flatter slopes. For steeper slopes soil bunds are recommended (SLMP, 2010).

Vegetated stone-soil bunds are practiced in high rainfall areas and on steeper slopes to reduce floods. In the process of controlling soil erosion in the upper watershed, the use of vegetated stone-soil bunds, provide benefits to cultivated lands in the valley bottoms. In the Farta District, which is close to Fogera, paved and grassed water way technology is practiced in 34 kebeles as an effective mechanism to trap and safely direct rainwater to natural drainage systems. The technology was found to be suitable on steeper areas, resulting in enhanced soil moisture and water harvesting, effective soil erosion control and reduced gully erosion (SLMP, 2010).

CCTs or hill side terraces (Plate 6a) are practiced in low to high rainfall (250 to 3000 mm) regimes, and mild to steeper slopes (5 to greater than 60% slopes). The technology breaks the speed of fast moving water, traps rainwater and enables it to percolate to underground aquifers. The technology does not require the use of stones and is positively perceived by farmers because of its effectiveness. It is also actively promoted by the extension service in Ethiopia (SLMP, 2010). Stone Bunds across the slope (Plate 6b) arrest the flow of water and control erosion in areas where soil work is not possible. Vegetated bunds and planting along CCTs (Plate 6c) increases biomass, conserves water and controls erosion. Contour Bunds and Field Bunds on waste lands and arable lands also improve soil moisture retention and control erosion and promote the growth of grasses, trees and tree crops.

Drainage line treatments

Drainage line treatments comprise gully plugs, earthen and stone dams and masonry structures which slow down runoff, and promote infiltration along the length of a drainage line, thus ensuring rapid and substantial groundwater recharge. Gully Plugs and Nala Bunds help control the flow of water, and sedimentation and recharge ground water aquifers. Check dams and percolation tanks may be constructed at the lower end of the drainage outlet and serve as storage basins for surplus Ridge to Valley conservation runoff water.

Afforestation and pasture development

This refers to plantation of trees, grasses and shrubs that meet household needs of fuel, fodder, timber, fruits and fiber. In areas where soil depth is not sufficient, pastures need to be developed. The trees, shrubs and grasses not only add organic matter to the soil, but also control erosion, cushion the ‘hammer effect’ of falling rain, slow runoff and accelerate infiltration.

CONCLUSION AND RECOMMENDATIONS

In many places where they have been applied in both India and Ethiopia, RMS have contributed to increased food security and increased livelihood services for the poor. However, where they are badly implemented they can have the opposite effect, increasing poverty and worsening food security. It is therefore essential that interventions are well planned and implemented. Designing and implementing successful and sustainable interventions requires detailed understanding of both the biophysical and socio-economic environment. Voluntary participation of the community right from the inception stage of the watershed development forms the foundation for the success of the watershed development programs. This paper has described the biophysical research being undertaken as part of the NBDC, which is intended to provide baseline information into the hydrological regimes, water use and productivity, prerequisites for the design of appropriate interventions. It is hoped that, in combination with insights gleaned from the socio-economic components of this research, this will provide knowledge that can contribute to better understanding of the factors that make interventions successful.

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