Fighting famine and poverty through water harvesting in Northern Ethiopia

Mintesinot B., Kifle W. & Leulseged T.

Mekelle University, P.O.Box 231, Mekelle, Ethiopia

'BRIGHT SPOTS'
reversing land and water degradation

COMPREHENSIVE Assessment of water management in agriculture

Summary

This paper presents a case study on successful water harvesting strategies that effected a reduction in recurrent famine and poverty in northern Ethiopia. The government of Ethiopia has invested in the construction of various surface water harvesting schemes including micro-dams and diversion weirs) as a result of which, a number of positive benefits have been recorded. These include: improvement in the socio-economic condition of the local community through small-scale irrigation; recharge of groundwater aquifer systems due to seepage water from surface reservoirs; improvement in the quality of groundwater systems as a result of water replenishment from the surface reservoirs; improvement in the environmental and micro-climatic conditions of the areas; and improvements in the overall water security of the people.

Background

Ethiopia is one of the most drought prone countries in the world, with a significant proportion of the net gross domestic product (GDP) dependent on rainfed agricultural practices. The intensity and duration of rainfall is highly erratic and variable, resulting in significant reductions in agricultural production and in some cases total crop failure. To avert or reduce the threat of complete crop failure and promote food security, effective planning and development of water resources becomes critically important. The dominant source of water used to supply major towns and rural communities is from wells and springs. The rapid growth of populations in both urban and rural areas has drastically increased the demand and has hence placed significant stress on water resources of the country. The number of small, medium, and large-scale industries that require significant amounts of water has also increased in the country adding further stress on these limited resources. In order to satisfy these competing demands for water, the Ethiopian government has been involved in the construction of surface water harvesting structures as a means of increasing supply. The major benefits resulting from water harvesting include: socio-economic, hydrological, environmental and an enhancement in biodiversity.

The paper discusses changes in water quantity and quality from various sources (wells, springs and surface storage structures) associated with the construction of water harvesting structures in Tigray over the period 1995 to 2000. , with a special focus on future water resources development and management endeavors in arid to semi-arid environments of Ethiopia.

Benefits of water harvesting

Socio-economic benefits

Before the construction of surface water harvesting schemes, people would have to travel long distances (up to 15 km) to collect drinking water and to water their animals. After the construction of water harvesting structures, people and livestock have enough water even during the drought periods (Figure 1).

Through small-scale irrigation practices, the local farmers are also improving their income even during the drought periods. On average, a two-fold increase in income is obtained through good small-scale irrigation management (Mintesinot *et al*., 2002).

Figure 1. Improved water supply for live stock during periods of severe drought.

Hydrological benefits

Effects of surface water harvesting on groundwater recharge to wells

Different types of surface water harvesting structures (dams, ponds and diversions) were constructed for the purpose of irrigation and water supply, over the past 8 years. Through the development of these structures significant positive effects on ground water recharge has occurred. Through a process of monitoring both deep and shallow wells constructed before 1995 and 2000 changes in the static water level and water quality as measured by total dissolved solids (TDS) were recorded at selective sites Tigray (Table 1). Well depth ranged from 45.4 m at Adi-gudom well No 5 to 70.8 m at Agula well No 3. Of the five wells monitored at Adi-gudom in 1995, two were dry. As a result of increased recharge associated with water harvesting structures all wells at Adi-gudom were yielding water in 2000, with well No 5 going from dry to a static water level of 12.5 m (Table 1). The static water level at the three wells at Agula deteriorated over the monitoring period with well No 3 drying up. A similar deterioration in static water level was observed at Negash (Table 1). Associated with the rise in static water level within the wells, there was in most cases a corresponding increase in the quality of the water with respect to TDS (Table 1). The greatest decline in TDS occurred at Adi-gudom well No 4 where the TDS declined from 1650 to 1000 mg/l over the monitoring period.

Table 1. Changes in the static water level and water quality from selected wells in Tigray before and after the construction of surface water harvesting structures (Kifle *et al*., 1995; Kifle 2000).

Locality Name		**Well Depth (m)**	**Before constructing surface water harvesting structures**		**After constructing surface water harvesting structures**	
			Static Water Level[1] (m)	**Water Quality (TDS) (mg/l)**	**Static Water Level[1] (m)**	**Water Quality (TDS) (mg/l)**
Adi-gudom	Adi-gudom W1	50.5	45.5	1600	38.5	900
	Adi-gudom W2	45.7	Dry	nd	27.3	1000
	Adi-gudom W3	60.3	50.5	1400	33.5	890
	Adi-gudom W4	55.2	48.6	1650	35.2	1000
	Adi-gudom W5	45.5	Dry	nd	12.5	850
Agula	Agula W1	55.0	Dry	nd	Dry	nd
	Agula W2	65.5	55.4	1450	60	1650
	Agula W3	70.8	60.7	1200	Dry	nd
Negash	Negash W1	67.6	55.5	850	Dry	nd
	Negash W2	55.5	35.8	1005	45.4	1250
Feleg waero	Feleg waero W1	65.5	50.3	1250	35.8	980
	Feleg waero W2	50.2	35.2	1450	22.3	1000
	Feleg waero W3	70.1	55.3	1340	28.5	850
Aba'ala	Aba'ala W1	65.5	55.8	1450	40.4	970
	Aba'ala W2	45.8	40.5	1340	30.3	1150
	Aba'ala W3	60.4	53.1	1270	45.5	880
	Aba'ala W4	70.0	48.6	1100	40.2	805

[1] The static water level is measured from the ground surface.
nd = not determined due to well being dry.

It is clearly evident that surface water harvesting has had a significant impact at different localities on the recharge of groundwater systems. This has resulted in an increase in groundwater yield, a decrease in groundwater depletion, and a favorable improvement in the quality of water from these wells.

Effect of surface water harvesting on groundwater recharge to springs

Many springs that issue at the contact zone between rocks/soils of highly permeability contrasts are common in Tigray. These natural water sources are important water sources for communities and their livestock. During drought periods it is a common observation that many of the small streams and springs dry-up. However, in downslope locations where surface water harvesting schemes were developed, new springs have occurred providing economic benefits to the respective localities. These natural springs within the same localities of the previously discussed wells were monitored over the period 1995 to 2000 for water yield and quality attributes (Table 2). It is interesting to note that springs in the Agula and Negash areas were affected by the development of water harvesting structures (Table 2). Spring yields either deteriorated or were unaffected by changes in water harvesting. However, in 12 out of the 17 springs monitored there was a significant improvement in water yields as well as quality (Table 2). The largest increase in water yield was observed at Feleg waero S3 where the in 2000 the yield had increased to 25 l/sec from 0.5 l/sec (Table 2).

In interviews undertaken with farmers that used these springs they indicated that most of the new springs that issued as a result of the newly built reservoirs did not dry up during even the worst drought and lowest rainfall seasons. As a result of the development of these surface water harvesting structures, there has been an increase in spring discharge that has enabled favor sustainable spring development for different purposes such as water supply, irrigation and industrial use.

Table 2. Discharge and quality of spring water before and after the construction of surface water harvesting structures (Kifle *et al*, 1995; Kifle, 2000)

Locality Name		**Before constructing surface water harvesting structures**		**After constructing surface water harvesting structures**	
		Spring Discharge (l/sec)	**Water Quality (TDS) (mg/l)**	**Spring Discharge (l/sec)**	**Water quality (TDS) (mg/l)**
Adi-gudom	Adi-gudom S1	Dry	-	5	850
	Adi-godom S2	Dry	-	7	1050
	Adi-godom S3	Dry	-	10	800
	Adi-gudom S4	0.5	1000	13	980
	Adi-gudom S5	1	905	15	870
Agula	Agula S1	Dry	-	Dry	-
	Agula S2	0.5	980	Dry	-
	Agula S3	0.2	1150	Dry	-
Negash	Negash S1	0.3	880	Dry	-
	Negash S2	Dry	-	Dry	-
Feleg waero	Feleg waero S1	Dry	-	13	960
	Feleg waero S2	0.8	1250	10	1110
	Feleg waero S3	0.5	1250	25	1005
Aba'ala	Aba'ala S1	Dry	1450	11	1250
	Aba'ala S2	5	1340	15	1210
	Aba'ala S3	Dry	-	10	800
	Aba'ala S4	2.5	1100	17	995

Water quality from micro-dams versus quality from wells and springs

The physical, biological and chemical quality of water was determined by taking water samples from surface reservoirs, springs, and wells. The pH of these sources ranged from 7.5-9.5. The results of the analysis are indicated in Table 3. The turbidity of the water in surface storage structures was slight to highly turbid with a color ranging from green to grey (Table 3). Contrasting this water, collected from wells and springs were clear with no suspended sediments or algal contamination. In the localities where there has been intensive surface water harvesting activities the value of the Total Dissolved Solids (TDS) in the groundwater and spring water was found to decrease after the construction of the surface reservoirs. The reduction in the value of TDS is related to the groundwater recharge and replenishment. In the localities where there has been limited or no surface water harvesting activities, the value of the Total Dissolved Solids (TDS) in the groundwater and spring water was found to increase. The reduction in the quality of groundwater in the areas where there has been poor groundwater recharge is related to groundwater depletion. Contamination by coliform bacteria was evident in waters collected from surface structures whereas wells and springs were clean (Table 3).

Table 3. Summary of selective physical, biological and chemical properties of water sampled from surface reservoirs, springs, and wells after the construction of water harvesting structures (Kifle, 2000).

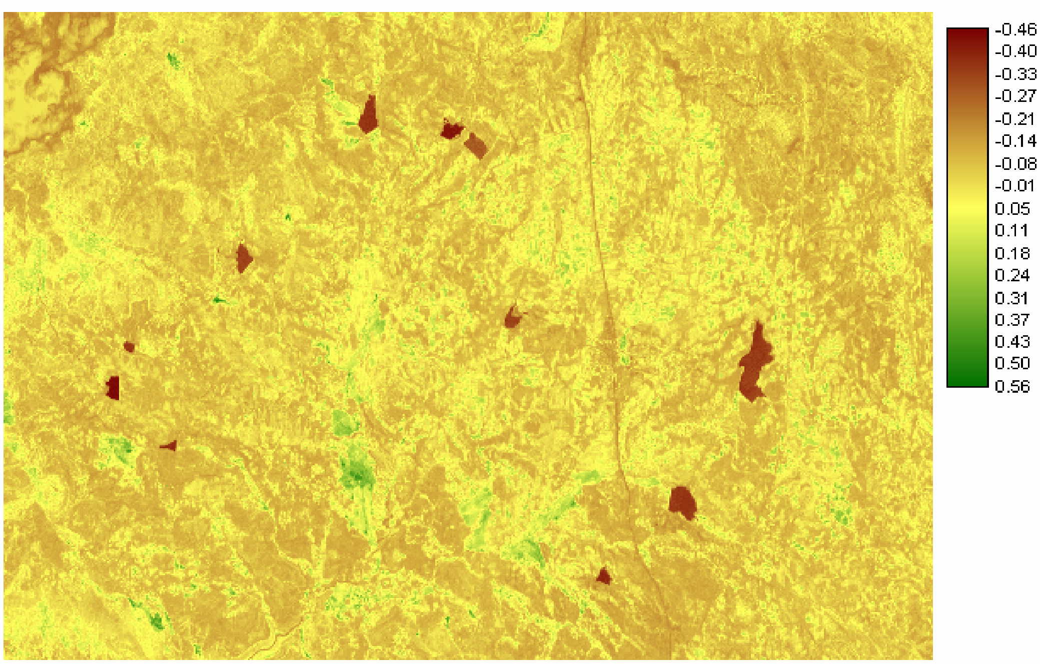
Source	Water Quality Attribute			
	Color	**Turbidity**	**TDS (mg/l)**	**Pathogenic organisms (coliform bacteria) (MPN[1] /100ml)**
Surface Water	Variable[2]	Slightly to highly turbid	780 – 1000	Positive (2 counts) for coliform bacteria
Spring water	Clear	Clear	800-1250	Free
Groundwater	Clear	Clear	805 – 1650	Free

[1] MPN is an abbreviation for Main Problem Number: it is a measure of the concentration of coliform bacteria in a water sample of 100ml.
[2]Water from surface reservoirs is observed to have variable color (from light gray to light green) and with some turbidity.

Greenness of the Environment

After the construction of water harvesting structures, the microclimate of the surrounding the areas has been improved. In this respect the hot and dry air that dominated these areas has been replaced by moist and cool air that has had a positive influence on the micro-climate surrounding the dams. Increases in vegetation improved after the construction of micro-dams. This can be qualitatively assessed by comparing the vegetation downstream and upstream of the dams. The Normalized Difference Vegetation Index (NDVI) map derived from ASTER satellite image demonstrates the significant improvement of greenness behind the reservoirs as compared to the dry and poorly vegetated environment upstream of the reservoirs (Figure 2).

Figure 2. NDVI image showing the contrast in "greenness" between areas upslope and downstream of reservoirs associated with enhanced ground water echarge.



The enhanced greening of the area is a direct impact of improved water resources after the construction of reservoirs. The green areas represent irrigated fields and/or grazing areas replenished by ground water recharge, seepage and/or application of irrigation water.

On the embankments of most of the water harvesting structures grass species have appeared and dominate the areas providing hay making materials and livestock grazing. Farmers are now able to make hay for livestock from these new sites allowing feed to be stockpiled for the dry months and drought periods.

Water harvesting to arresting aggravated erosion processes

Soil erosion is a significant land degradation issues facing Tigray. In appropriate land management practices and over grazing has resulted in sheet and gully erosion (Fitsum *et al*., 1999; Eweg *et al*., 1997; Nyssen *et al*., 2000; Berhanu, 1998). The consequences of excessive soil loss have been declining crop yields and further degradation of natural resources (Eweg *et al*., 1997). However, there are little quantitative and in some cases contradictory information available on the magnitude of the problem and the role of the various factors causing the issue, that prevent the making of sustainable resource management decisions. Most studies that have been undertaken in the region have focused on the on-site effects of soil erosion ignoring its off-site impacts such as reservoir sedimentation and pollution (Figure 3). Especially in light of the region's effort to increase the supply of water for irrigation and drinking purposes, the off-site effect of erosion is one that should also be given due emphasis particularly when excessive sediment deposition will influence water quality, storage capacity and life expectancy of the storage structure.

Figure 3. Sediment deposition with in a reservoir associated with erosion in the upper catchment.

Some studies undertaken on reservoir sedimentation indicate that the reservoirs constructed in the basin are able to prevent huge amounts of soil from being displaced from catchments. A study conducted by Hadera and Girma (1999) on three reservoirs indicates that between 8000 to 75000 tons of soil have been accumulated behind dams. Similar studies conducted on twelve reservoirs indicated a specific sediment yield of 32-35 t/ha/year (Lulseged et al, submitted). This indicates the off-site benefits of reservoirs to reducing soil loss and erosion downslope, although this will have an impact on the useful life of these storage structures.

Biodiversity benefits

There is evidence to support the argument that with the eradication of forest cover in Tigray wildlife has been forced to migrate from these areas. This has contributed to the loss and/or reduction of biodiversity in the region. Contrary to this, new species of animals and birds have started to emerge around and within the micro-dams after their construction. This has resulted in very attractive scenery around the dam sites (Figure 4). Migratory birds move between the micro-dams and the wastes products from the birds is becoming a very important source of nutrients in the area.

Figure 4. As a resulted on improved habit, water birds are beginning to inhabit the fringe areas of these micro-dams.

In some areas fish have been introduced into the reservoirs in order to provide economic benefits to communities in the areas. Even though no exploitation of the fish resource is currently taking place, it signals that if systematically handled, the reservoirs will also provide additional food security through another alternative means of subsistence.

Concluding remarks

Food insecurity is a major issue in Ethiopia. This problem is more serious in the dryland areas where rainfall is low and within and between year variability is high. The recurrence of drought is on the rise and having a significant impact on the ability of household and communities attaining food security.

With the growing demand for food and continued struggle to achieve 'long term food security', there is a dire need to maximize productivities of both land and water. Inputs to land may improve land productivity but inputs to water may not change the productive capacity of water. Improving the water security through increasing the water use efficiency (more crop per drop) can however result in higher productivity (Mintesinot, 2002).

The issue of water security in Tigray (Northern Ethiopia) is crucial. The region has been facing a massive crisis in the supply of water for domestic and irrigation purposes. Many traditional sources of water, such as springs and streams, have dried-up resulting in recurrent drought, famine and food insecurity.

To curb the food insecurity problem of the people and also satisfy the policy of the government (agricultural led industrialization), attempts are being made to increase the productivity of the agricultural sector of the economy. This can be achieved through tackling the major factors affecting its productivity, namely a shortage of water. Currently it is estimated that the existing surface water resource potential of the nation is approximately 2.56 billion cubic meters (Wondimbeza, 2002) of which only 1.2% is used for irrigation purpose (Lemma, 2002).

Recognizing the fact that construction of micro dams with proper management results in improved livelihood with positive impacts on microclimatic and environmental conditions, attempts are being made to harvest run-off water in micro-dams for use both in households and small-scale irrigation schemes. The construction of these schemes resulted in various benefits to the society and general ecology of the surrounding areas. Farmers are able to increase production by three fold (Haftu, 2001) and double the cropping intensity on an annual basis. This has brought positive benefits to nearby urban areas where fruits and vegetables are more readily available and inexpensive. People are able to fetch water from nearby and also water their livestock easily without traveling longer distances.

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