MONITORING PRODUCTIVITY OF WATER IN AGRICULTURE AND INTERACTING SYSTEMS: THE CASE OF TEKEZE/ATBARA RIVER BASIN IN ETHIOPIA

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Abstract

The Haiba irrigation scheme is located in northern Ethiopia, Tigray Regional State, in the eastern part of the Tekeze River Basin. The basin has a total area of about 65. 45 km^2.

The study area includes a small dam called Haiba dam. The average water holding capacity of the dam at the time when it was constructed was 3 x 10^6 m^3. The effective watershed area of the dam is 38 km^2. The command area is located 2.5 km from the dam axis in the valley bottom surrounded by mountainous land formation, and has an area of about 300 ha.

Based on the water productivity assessment, the scheme is characterized by poor water management. The computed diverted water productivity was 1.84 kg/m^3 for potato, 1.07 kg/m^3 for onion and 0.23 kg/m^3 for maize. Wheat has the lowest water productivity, 0.08 kg/m^3. Rainfall water productivity was highest for wheat followed by maize and teff; 0.38 kg/m^3, 0.28 kg/m^3, and 0.19 kg/m^3, respectively. In general, for the crops that are commonly practiced by the farmers during both irrigation and rainy seasons the rainfall water productivity is greater than that of the diverted water productivity, which is a clear indication of inefficient water management in the scheme.

With the exception of teff, in general, the diverted and the rainfall water productivity values of both vegetable crops and cereal crops are less than 50 per cent of the respective potential productivity values.

Economic water productivity assessment show that the difference in the economic value is mainly associated with yields variation. Onion (0.29 USD/m^3), potato (0.24 USD/m^3) and maize (0.04 USD/m^3) having highest economic water productivity under irrigation condition

with wheat the lowest (0.02 USD/m^3). On the other hand, wheat has the highest economic water productivity (0.19 USD/m^3) in the rain fed agriculture followed by teff (0.11 USD/m^3) and maize (0.08 USD/m^3).

1. Description of the Study Area

1.1 Location

Tekeze River Basin

The Tekeze River commences from the highlands in the south and drains central, southern and a larger portion of the western Tigray westward to the Nile. The length of the Tekeze River from its source down to the Sudanese border is more than 600 Km. The basin has an average elevation of 1850 m above sea level and a catchment area of about 68, 000 km2. About 70 per cent of the basin lies in the highlands at an altitude of over 1500 m above sea level. The lowlands are found in a strip of land of about 150 Km long and 30 to 100 Km wide along the Sudanese border. Here the elevation varies between 500 and 1000 m above sea level.

The Haiba Irrigation Scheme

The irrigation scheme is located in the Haiba basin, southern zone of Tigray Regional State, around 45 km from the regional capital Mekelle, northern Ethiopia. From hydrological point of view, it is located in the eastern part of the Tekeze River Basin. Geographically, it lies between longitude of 39° 12' and 39°20' E and latitude of 13° 15' and 13° 20' N. The basin has a total area of about 65. 45 km^2 (Fig. 1).

1.2 Physiogrphy and Drainage

The topography of the area is not uniform. It consists of mountains, highlands and terrains of gentle slopes. The mountains are found surrounding the study area. The highlands are extended down from the bottom of the mountains to the valley where they terminated as a lowlands having gentle slope. The average elevation of the study area is 2, 300 m above sea level.

The study area is drained by an intermittent river called Haiba river. It commenced from the northeaster highlands and flows southwest to the Tekeze River. The study area includes a small dam called Haiba dam. The dam was constructed having its face towards the

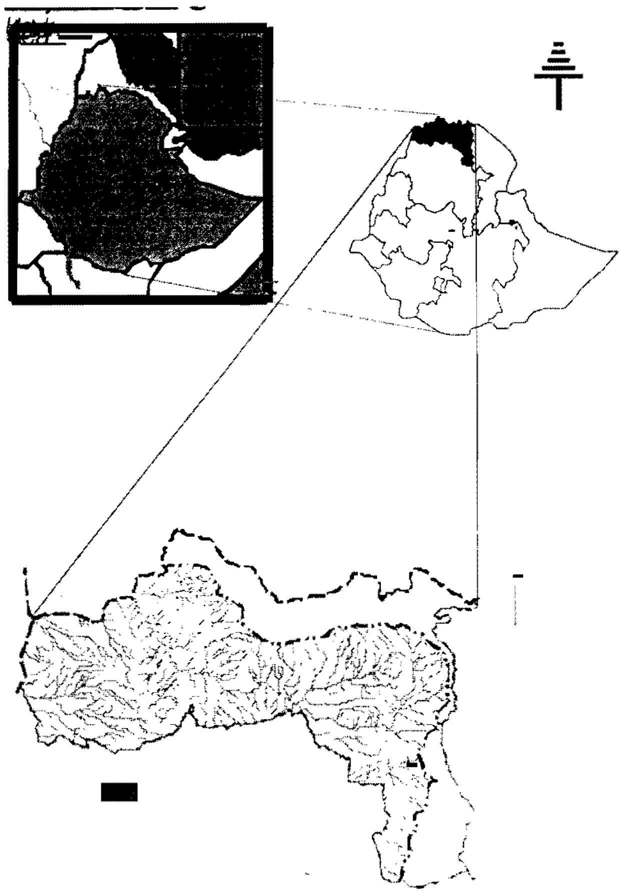

Fig. 1.1. Location Map of the Study Area.

direction of the Haiba river flow. The average water holding capacity of the dam at the time when it was constructed was 3×10^6 m^3. The effective watershed area of the dam is 38 km^2. The command area is located 2.5 km from the dam axis in the valley bottom surrounded by mountainous land formation, and has an area of about 300 ha. . It is crossed by the Haiba river gully. Standing face towards the direction of the river flow the land in the left-hand side of the gully is the main land to be commanded. The land surrounding the command area and contributing water to it during rainy season has an area of 24.45 km^2.

1.3 Land Use

The land use pattern in the scheme is as shown in the table below. The area taken to be rain fed cropland is the summation of the total area covered with crops in the long rainy season in 1995/96-crop season. The catchment covers a total area of 6545 km^2.

Table 1.1. Existing Land Use Pattern.

No.	Category	Area (ha)
1	Crop land (rain fed)	3247.4
2	Irrigated land	300.00
3	Area closure	2068.2
4	Land with no vegetation (desert)	229.1
5	Area left for forest plantation	700.3
Total		6545

1.4 Soil

The land is dominated by heavy textured soil of alluvial and colluvial nature derived from limestone, shale and dolerites that are found dominantly underlying the area. The thickness of the soil is not uniform through out the study area. Soils of colluvial nature have found having a small thickness bordering the mountains. The alluvium are dominantly found on the left and right side of the river channel having a thickness ranging from 3 – 9 m. the color of the soil is black. Mud crakes that have an average opening size of about 1 mm are a common structure that is found in this soil.

1.5 Vegetation

Like other parts of the Tigray region, the study area is highly affected by deforestation process. Vegetations are found largely scattered around cultivable land, grazing land and churches. Olia erupean, Euphorbia candelabrum, acacia saligina, *Faidherbia albida,* and Ficus vasta are some of the species of trees that are found in the area.

1.6 Farming system

There is no model farming system in the area, instead the peoples of the study area are very dependent on traditional farming system that helped by local constructed farm implements. They use local available materials such as logs and animal skin for making such farm implements. Almost all of the peoples in the study area are entirely dependent on agriculture in which animal husbandry and crop production plays a major role.

The major crops grown under rain fed and irrigation are barely, wheat, teff, figure millet, beans, maize, onion, tomato, cabbage, kosta, and potato. The most serious problem for the agriculture production is the shortage of land holding. Average household farm size is 1.25 ha, but there are inhabitants with no farmland. In comparing the population of the area with the total arable land, the size of land per capita will be much lower than 0.25 ha.

1.7 Cropping Pattern

Wet season, short rainy season (April - May) and long rainy season (June - September), and irrigation season (November - June) are the main agricultural season. Detail on cropping calendar (sowing date, harvesting date) is given in the table below.

The major dry season crops include maize, wheat, onion, bean, peas, cabbage, tomato, potato and spice crops. Maize, wheat, barely, bean, teff, creak pea, lentil, and peas are rain fed crops. Oil crops like linseed and sesame are grown in small area. In rare cases sunflower is intercropped with teff. Peas are also grown with irrigation.

Table 1.2. Yearly Cropping Calendar (Wet Season).

Crops	Jun	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Wheat						15th-	---	---	---	28th		
Teff							11th--	---	---	---	---	---18th
Pulse (Beans)							1st---	---	---	--8th		
Maize				15th	---	---	---	---	12th			

Table 1.3. Yearly Cropping Calendar (Dry Season).

Crops	Jun	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Wheat	---	---	25th								10th--	---
Sunflower	---	---	10th								1st--	---
Onion	---	---	15th							16th	---	---
Peas	---	---	20th									21st---
Pulses (Beans)									20th	-----	-----	---29th

2. Methodology

This study was conducted in the Haiba micro dam irrigation scheme in the Tekeze River Basin. The data for the study was collected from both primary and secondary sources.

From the raid reconnaissance survey made on three micro dam sites, only the Haiba micro dam was selected for the PWAIS project on the basis of agro-ecology, availability of secondary data and accessibility to the sites. The site is located in the more representative sub-basin of the major Tekeze river basin.

Crop area, cropping pattern, crop yield and livestock populations were obtained from site agricultural office. Actual field measurements were conducted to determine the volume of water harvested and flow rate in the main and secondary canals, respectively, during the months from February to June 2004.

Besides to the actual field measurements, the primary data was also obtained from a formal household questionnaire survey, key informant discussion and direct observation. The sample population for the study was only the household that used irrigation water from the dam. The sample was designed in such a way that is representative for the total household using irrigation scheme. By using systematic random sampling a total 100 household were interviewed from total irrigation users. To supplement the household survey focus group discussion was also conducted.

The questionnaires generally included questions that indicate option for improving water productivity, historical and current productivity in the basin, knowledge transfer (flow) and impediment to knowledge transfer. Moreover, some general information of the scheme and socio-economic condition of the community were obtained from key informant discussion at the site level. In the discussion focusing groups extension service, knowledgeable farmers had participated.

The social survey data was analyzed using SPSS software to obtain percentage of respondents.

For crop water Productivity assessment, due to the unavailability of meteorological station at the site, climatic data were collected from the nearest meteorological station.

3. Results and Discussions

3.1 Water Productivity

Table 3.1 and 3.2 below show the water productivity under irrigation and rain fed agriculture for the major crops grown in the area, respectively.

Table 3.1. Irrigation Water Productivity for 2004/05 Irrigation Season.

Crop	Water supplied (diverted)* (mm)	CWR (mm)	Yield (Kg/ha)**	Maximum Potential Yield (MPY)*** (Kg/ha)	Crop Water Productivity (kg/m^3)	
					Diverted WP	Potential WP****
Wheat	1350	415.75	1, 060.00	5, 500.00	0.08	1.32
Onion	1230	503.1	13, 182.00	30, 000.00	1.07	5.96
Beans	-	289.68	1, 040.00	-	-	
Potato	984	460	18, 142.00	18, 000.00	1.84	3.91
Maize	861	332.93	2, 000.00	6, 700.00	0.23	2.01

*: The amount of water supplied or diverted is the amount of water released just at the reservoir outlet. It is the gross irrigation water requirement.

**: The yield data was for 2004/05 irrigation seasons.

***: Source: Community Based Irrigation Management in Tekeze River Basin, 2004.

****: MPY/CWR

Table 3.2. Rainfall Water Productivity

Crop	Rainfall (mm) & Crop Water Requirement (mm)			Yield (Kg/ha)	Maximum Potential Yield (MPY)* (Kg/ha)	Productivity (kg/m^3)		
	Total (P) (mm)	Effective (Pe) (mm)	CWR (mm)			PWP	PWPe	Potential WP**
Wheat	425.92	216.925	259.26	1, 600.00	5, 500.00	0.38	0.74	2.12
Teff	425.92	216.925	394.08	800.00	2, 200.00	0.19	0.37	0.56
Maize	425.92	216.925	332.93	1, 200.00	6, 700.00	0.28	0.55	2.01

*: Source: Community Based Irrigation Management in Tekeze River Basin, 2004.

**: MPY/CWR

The diverted water productivity was highest for potato followed by onion and maize, 1.84 kg/m^3, 1.07 kg/m^3, and 0.23 kg/m^3, respectively. Wheat has the lowest water productivity. The result shows that the vegetable crop has the highest water productivity compared to the cereals crop. This may be attributed to the better input and better management irrigator gives to these crops. The diverted water productivity for potato is 47 per cent of the potential productivity: onion and maize has 17 per cent and 11 per cent, respectively. In general, the diverted water productivity values of both vegetable crops and cereal crops are much more less than the respective potential productivity values. This indicates the existence of lowest irrigation efficiency in the scheme.

Rainfall water productivity was highest for wheat followed by maize and teff; 0.38 kg/m^3, 0.28 kg/m^3, and 0.19 kg/m^3, respectively. The same is true for effective rainfall water productivity; 0.74 kg/m^3 for wheat, 0.55 kg/m^3 for maize, and 0.37 kg/m^3 for teff. The lowest water productivity was for teff, because this crop provides less yield per hectare compared to other cereal crops in the region. However, the effective rainfall water productivity for teff is 66.07 per cent of the potential productivity, which is an indication of a better productivity performance as compared to the other cereal crops. The effective rainfall water productivity of wheat and maize is 34.91 per cent and 27.36 per cent of their respective potential productivity.

Maize and wheat are the common cereal crops that usually practiced by the farmers both under rain fed and irrigated agriculture. The water productivity assessment shows that the rainfall water productivity for wheat is more than four times that of the diverted water productivity. The water productivity assessment also shows that the diverted water productivity for maize is less than the rainfall water productivity. This is a clear indication of inefficient water management in the scheme. The PW variation among the crops is mainly attributed to the yield variation between the crops.

3.2 Economic Water Productivity

Table 3.3 to 3.4 show the economic crop water productivity in ETB/ m^3 and USD/m^3 under irrigation and rain fed conditions. In order to calculate the economic water productivity average price of the common crops in the region for the irrigation (May – June) and rain fed (December- January) market seasons was taken.

The water used for calculation includes both the actual diverted /supplied water and the actual water consumed by the crop.

Economic productivity of diverted water was highest for onion, 0.29 USD/m^3, followed by potato, 0.24 USD/m^3, and maize, 0.04 USD/m^3. Wheat had the lowest economic water productivity.

Under rain fed condition, wheat and teff have the highest value, 0.19 USD/m^3 and 0.11 USD/m^3, respectively, whereas maize has the lowest, which is 0.08 USD/m^3. The result shows that the difference in the economic value is mainly associated with yield variations. Onion, potato and maize having highest economic water productivity under irrigation condition with wheat the lowest. On the other hand wheat has the highest economic water productivity in the rain fed agriculture.

Table 3.3. Economic Water Productivity under Irrigation (Diverted Water).

Crops	Irrigated Crop						
	Kg/ha	Price of Crop (ETB/kg)	Price of Crop (ETB/ha)	Diverted Water (mm)	Diverted Water (m^3)	ETB/m^3	USD/m^3
Wheat	1, 060.00	1.75	1, 855.00	1350	13500	0.14	0.02
Onion	13, 182.00	2.29	30, 186.78	1230	12300	2.45	0.29
Beans	1, 040.00	1.92	1, 996.80	-	-	-	-
Potato	18, 142.00	1.12	20, 319.04	984	9840	2.06	0.24

Maize	2, 000.00	1.5	3, 000.00	861	8610	0.35	0.04

Table 3.4. Economic Water Productivity under Rain fed (Effective (Pe)).

Crops	Rain fed Economic Crop Water Productivity						
	Kg/ha	Price of Crop (ETB/kg)	Price of Crop (ETB/ha)	Effective (Pe) (mm)	Effective (Pe) (m^3)	ETB/m^3	USD/m^3
Wheat	1, 600.00	2.22	3552	216.925	2169.25	1.64	0.19
Teff	800.00	2.59	2072	216.925	2169.25	0.96	0.11
Maize	1, 200.00	1.24	1488	216.925	2169.25	0.69	0.08

1.Assuming current exchange rate of 1USD = 8.5 ETB

2. Price of crop for irrigation season (May – June) and rain fed (December – January) was obtained from regional average.

3.3 Interacting Systems

Beside the irrigation water use, the water from the reservoir is used for domestic and livestock watering. The majority of the villagers and their livestock are dependent from the water source in the dam and shallow wells constructed in the command area.

If the present trend is continues more water is needed in the future for the increasing number of populations and livestock number in the study area, as a result the scheme is under pressure to accommodate these water demand and water need of the agriculture sector. On the other hand water storage capacity is diminishing due to siltation and climatic variability. But with conjunctive use of surface and groundwater it is possible to address some of the problems and at the same time the pressure in the reservoir water will be curbed.

3.3.1 Domestic Water Use

Peoples in the upstream villagers are more dependent on groundwater, which have good quality. The other villagers are both using water from the hand dug wells, spring and river. Only those nearer to the reservoir are using the reservoir water. From the total 100 interviewed households those using water from groundwater, river and spring, and reservoir are 62 per cent, 24 per cent and 7 per cent, respectively. The other 7 per cent are dependent on combination of the water sources available (Table 3.5).

Table 3.5. Drinking Water Source for Domestic Needs.

Source of Water	Frequency	Per cent	Valid Per cent	Cumulative Per cent
Reservoir Only	7	7	7	7
Near by River and Spring	24	24	24	31
Dug Wells	62	62	62	93
Spring	3	3	3	96
River Only	3	3	3	99
Reservoir and Dug Wells	1	1	1	100
Total	100	100	100	

Source: Social Survey, 2004/05

Totally in the scheme there are six hand dug wells which are fitted with hand pump. Four of these wells are located in the command area while the remaining are in the upstream side. The water from these wells are used for both domestic and livestock consumptions. There are also two springs that provide water for both domestic and livestock purposes. The intermittent river, Haiba, is also a source of water for the peoples. During the dry period the river flow is mainly dependent from excess drainage water from the command area and the seepage loss from the dam. The peoples use the water from this river for both their domestic and livestock consumptions.

Because of the groundwater potential created by seepage water from the reservoir a number of hand dug wells are now under construction in the command area. These are expected to provide multiple uses (irrigation, domestic and livestock). In this year alone (2004/05) 255 hand dug wells are constructed by the farmers. The over all intention of these hand dug wells is to supplement the water from the reservoir and to provide water for domestic and livestock consumptions. Besides, other farmers in the catchment area are also constructing open water harvesting ponds with the objective of supplementing the rain fed crops when soil moisture deficiency encountered. These structures together with the wells will make a significant contribution to curb the water scarcity and helps to bring other farmers who are out of irrigation because of water shortage.