African Journal of Agricultural Research Vol. 7(35), pp. 4956-4970, 11 September, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.2135
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Comparative irrigation performance assessment in community-managed schemes in Ethiopia

Zeleke Agide Dejen[1,2]*, Bart Schultz[1] and Laszlo Hayde[1]

[1]Department of Water Science and Engineering, UNESCO-IHE Institute for Water Education, Delft, Netherlands.
[2]Department of Water Resources and Irrigation Engineering, Arba Minch University, Arba Minch, Ethiopia.

Accepted 29 March, 2012

In this paper the performance of two community-managed irrigation schemes in Ethiopia were evaluated with comparative (external) indicators. Three groups of comparative performance indicators, that is, water supply, agricultural output and physical indicators were used to assess Golgota Scheme (command area = 600 ha) and Wedecha Scheme with two sub-systems with command areas of 300 ha (Godino) and 60 ha (Gohaworki). The results obtained show that while annual irrigation supply at Godino sub-system matched well to demand, at Golgota Scheme and Gohaworki Sub-system, excessive irrigation water was supplied with annual relative irrigation supply (ARIS) values of 3.20 and 1.90, respectively. Whilst Golgota Scheme had better land productivity in the region due to more intensive irrigation and better investment, it had poor water productivity due to uncontrolled water diversion and absence of irrigation water fee. Godino sub-system could be benchmarked in the region for water productivity; while land productivity at Golgota could be taken as a promising indicator. Irrigated areas at Wedecha (both sub-systems) were found to be contracting while it was expanding at Golgota due to more generous irrigation water supply for free.

Key words: Community-managed, comparative, performance indicators, irrigation water, productivity, sustainability.

INTRODUCTION

The pressure on land and water; the two central resources for irrigated agriculture has been rising globally from ever increasing global population. According to the Food and Agriculture Organization of the United Nations (FAO, 2003), expenditures for expansion of irrigated agriculture have significantly declined during the last two decades for major reasons of decline in fresh water and land resources. Irrigation expansion has slowed down drastically over the past two decades and the worldwide emphasis has been on the rehabilitation and management improvement of existing schemes (Plusqellec, 2009). On top of depleting water and land resources, the unit cost of development of new irrigation schemes is much higher than the unit cost of rehabilitation according to FAO (2003). With expected global increase in food demand of about 40% in the next 20 to 25 years and with decline of rate of expansion of irrigated area, enhancing water and land productivity in existing schemes through improved irrigation performance will be inevitable. In Ethiopia, about 90% of the irrigation potential in terms of land and water resources has not been developed so far. However, there have been many ongoing medium and large-scale irrigation developments in recent years. While about 47% of the developed area is under large-scale public irrigation schemes, mainly industrial crops such as cotton, sugarcane and various fruits are grown. About

---

*Corresponding author. E-mail: zelek2@unesco-ihe.org. Tel: +251(0)911830575. Fax: +31(0)152122921.

Abbreviations: AIDUIA, Annual irrigation water delivery per unit irrigated cropped area; **OPUIA,** output per unit irrigated cropped area; **OPUCA,** output per unit command area; **OPUIS,** output per unit irrigation water supply/diverted; **OPUID,** output per unit irrigation water delivered; **OPUWS,** output per unit water supply/diverted; **OPUWC,** output per unit water consumed.

65% of the irrigated area is under small-scale irrigation schemes; either modern or traditional (FAO, 2005). Traditional irrigation schemes are those developed by farmers themselves and are without permanent water diversion, conveyance, control and distribution facilities.

'Modern schemes' are those equipped with basic irrigation infrastructure such as water diversion and flow control structures and conveyance and distribution systems. Modern small-scale schemes account for about 18% of irrigated area to date, of which the schemes under the current study are examples. Small-scale schemes are operated and managed by the water users themselves with little involvement of government agencies in some cases. Ministry of Water Resources (MoWR, 2004) emphasizes that in Ethiopia, these schemes have been playing a significant role in ensuring food security at household level and in improving the livelihood of the rural poor. However, absence of continuous improvement initiatives and performance monitoring mechanisms have either challenged sustainable production or have resulted in wastage and misuse of scarce water resources in these schemes. Recently, efforts are being made to involve farmers in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, particularly, in water distribution and operation and maintenance to improve the performance of irrigated agriculture (Awulachew et al., 2007). However, Awulachew and Merrey (2006) state that lack of managerial, financial and technical capacity of water users is considered to be the major cause of failure in community-managed schemes. Sustainability of irrigation systems depend on a number of variables such as operation and maintenance, condition of irrigation infrastructure, institutional settings, land and water resources, etc. Improving the performance of irrigation systems requires setting some relevant criteria for performance and identifying indicators which can enhance the performance level. With so many elements of the agricultural system, it is apparently not easy to address all areas of performance at the same time. Burt and Styles (1999) distinguish between internal process indicators and external (comparative) indicators. Similarly, Molden et al. (1998) made a more or less similar distinction between these two kinds of indicators. From their perspective, while internal indicators are useful to assess performance against system specific operational targets, they offer very little for comparison of schemes.

Much effort has been made to evaluate internal irrigation performance in terms of flow rate, flexibility and duration of flow at the point of demand, mainly the tertiary canals. These are crucial to achieve equitable water distribution if the system is operated and maintained systematically (Hedayat, 2005) and would enhance equity, adequacy and dependability within a scheme. External (comparative) indicators on the other hand are useful for cross comparison of schemes without looking at internal system specific performance targets. Comparison aims to improve the performance of the schemes by identifying shortcomings and benchmarking best practices (Malano et al., 2004). This paper aims to evaluate and cross-compare the performance of two community-managed irrigation schemes; namely, Golgota and Wedecha located in Central Ethiopia with comparative performance indicators and put forward ways for improvement. Wedecha Scheme has two sub-systems called Golgota and Gohaworki being supplied from the same source of irrigation water. Molden et al. (1998) have summarized three groups of comparative performance indicators: agricultural output, water supply and financial indicators. The application of these indicators was described at 18 schemes located in 11 different countries based on data collected by the International Water Management Institute (IWMI) and collaborators (Molden et al., 1998). Similarly, Kloezen and Garcés-Restrepo (1998) applied these indicators to assess the Alto Rio Lerma Irrigation District in Mexico. While these indicators were employed in this study, financial indicators were not included as they are irrelevant to the systems under consideration (at Golgota Scheme, irrigation water fee is completely absent). Instead, physical indicators were defined and used.

On the other hand, two additional water productivity indicators, that is, output per unit irrigation water delivered to the head of the command (OPUID) and output per unit water supplied (irrigation + rainfall) (OPUWS) were also included in this study.

MATERIALS AND METHODS

The irrigation schemes

The Golgota and Wedecha Schemes are located in central Ethiopia in Awash River Basin. Golgota Scheme is supplied with water from the main Awash River with temporary diversions. However, at about 500 m from the temporary diversion there are sluice gates on the bank of the canal to regulate the flow. These sluices are used to release excess water from the canal back to the river and to scour sediment entering at the head of the canal. Water is conveyed in a totally earthen main canal and is distributed through three main tertiary off-takes equipped with sluice gates. The nominal command area of the scheme is about 600 ha. The two sub-systems; that is, Godino and Gohaworki of the Wedecha Scheme are supplied with water from Wedecha Reservoir. Water is taken through a piped outlet under the embankment dam and is conveyed via the natural river channel. At some 5 km distance from the dam, there is a diversion weir with off-takes on the right bank that supplies water to Gohaworki Sub-system. At 1 km downstream of the first weir is the second diversion weir with off-takes on the left bank that supplies water to Godino Sub-system. The regulating gates at both of these off-takes were demolished by farmers. Currently, flow into the canals is regulated at the off-takes with stones and wooden logs. Water is diverted into rectangular masonry lined canals at both off-takes and is distributed using poorly constructed earthen channels.

The nominal command area of Godino Sub-system is about 300 ha while that of Gohaworki is about 60 ha, with a combined nominal command area of 360 ha. Figure 1 shows location of the schemes.

Comparative (external) performance indicators

Comparative performance assessment in irrigation schemes is possible through use of comparative indicators. External indicators are those indicators based on outputs and inputs from and to an irrigated agricultural system (Molden et al., 1998). Internal indicators on the other hand relate performance to internal management targets (equity, adequacy and reliability). Internal irrigation performance is linked to farmers' level of satisfaction by some authors (Ghosh et al., 2005; Kuscu et al., 2008). Unlike internal indicators, external indicators inform on the impacts and outputs of irrigation with respect to the inputs and are practically less informative as to what internal processes resulted in the outputs. Although, in its very concept, external indicators link outputs to inputs, there are indicators for comparative purposes that are not necessarily based on outputs and inputs. Examples are water supply, financial and physical indicators. Three groups of relevant comparative performance indicators were used in this study to assess and compare the performance of the two community-managed irrigation schemes. These are water supply, agricultural output and physical sustainability indicators. Under each group, relevant performance indicators were identified and used for comparative assessment.

Water supply indicators

The water supply indicators are based on irrigation and water supply/delivery measurements being related to demands or irrigated area. Three indicators were considered under this group.

Annual irrigation water delivery per unit irrigated cropped area (m^3/ha)

This indicator quantifies the volume of irrigation water actually delivered per unit area irrigated in a year (Malano and Burton, 2001). In this study, delivered irrigation water to command head and the sum of irrigated areas during all seasons in a year were considered:

$$AIDUIA = \frac{\text{Annual water delivered}}{\text{Annual irrigated cropped area}},\quad m^3/ha \qquad (1)$$

Where, AIDUIA is annual irrigation water delivery per unit irrigated cropped area.

Annual relative water supply

This is the ratio of total annual water supplied (irrigation plus rainfall) to the annual crop water demand. It signifies whether the water supply is in short or in excess of demand:

$$ARWS = \frac{\text{Annual water supply}}{\text{Annual crop water demand}} \qquad (2)$$

Where, ARWS is annual relative water supply.

Annual relative irrigation supply

This is the ratio of annual irrigation supply to annual irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance in relation to irrigation demand. It is given by Molden et al. (1998):

$$ARIS = \frac{\text{Annual irrigtion supply}}{\text{Annual irrigation demand}} \qquad (3)$$

Where, ARIS is annual relative irrigation supply.

Agricultural output indicators

Agricultural output indicators can be subdivided into land productivity and water productivity indicators. Six relevant indicators, two for land productivity and four for water productivity were considered under this group of indicators. The outputs of agricultural production in this paper were based on local prices.

Output per unit irrigated cropped area (US$/ha)

It quantifies the total value of agricultural production per unit of area under irrigation during the period of analysis. The sum of the areas irrigated annually was considered in this study. In addition to water availability, soil type and fertility, land suitability, crop variety and agricultural inputs do have significant impact on land productivity. It is given as (Malano et al., 2004; Molden et al., 1998):

$$OPUIA = \frac{\text{Value of annual production}}{\text{Annual irrigated cropped area}},\quad US\$/ha \qquad (4)$$

Where, OPUIA is output per unit irrigated cropped area.

Output per unit command area (US$/ha)

This is the value of agricultural production per unit of nominal area which can be irrigated. Smaller values of this indicator imply, although, not necessarily, less intensive irrigation. It is particularly important where land is a constraining resource for production (Molden et al., 1998):

$$OPUCA = \frac{\text{Value of annual production}}{\text{Nominal area}},\quad US\$/ha \qquad (5)$$

Where, OPUCA is output per unit command area.

Output per unit irrigation water supply (US$/$m^3$)

This tells on how well the total annual diverted irrigation water from a source is productive. Irrigation water supply includes conveyance losses in canals. In areas where water is scarce, water management aims to increase the output per drop of irrigation water:

$$OPUIS = \frac{\text{Value of annual production}}{\text{Diverted anaul irrigation water}},\quad US\$/m^3 \qquad (6)$$

Where, OPUIS is output per unit irrigation water supply or diverted.

Output per unit irrigation water delivered (US$/m^3)

This is meant for the value of production per unit volume of annual irrigation water delivered to the head of command area. It is different from irrigation supply as it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. Inefficient water use results in lower values of this indicator:

$$\text{OPUID} = \frac{\text{Annual value of production}}{\text{Delivered annaul irrigation water}},\ \text{US\$}/_{\text{m}^3} \quad (7)$$

Where, OPUID is output per unit irrigation water delivered.

Output per unit water supply (US$/m^3)

This is for the output per unit of total annual volume of water (effective rainfall + irrigation) diverted to the system. It gives a sound comparison between irrigation schemes with different rainfalls, because gross water supply was considered:

$$\text{OPUWS} = \frac{\text{Annual value of production}}{\text{Total water supply}},\ \text{US\$}/_{\text{m}^3} \quad (8)$$

Where, OPUWS is output per unit water supply/diverted.

Output per unit water consumed (US$/m^3)

This indicator informs on the output per unit annual volume of water consumed by actual evapotranspiration. Its value is highly dependent on climate. Moreover, less consumptive use coefficient due to water losses does not affect its value; as only the water consumptively used by the crops is considered. It is given as (Molden et al., 1998):

$$\text{OPUWC} = \frac{\text{Annual value of production}}{\text{Water consumed by ET}},\ \text{US\$}/_{\text{m}^3} \quad (9)$$

Where, OPUWC is output per unit water consumed.

Physical sustainability indicators

Two relevant performance indicators were considered under this group as was enumerated by Şener et al. (2007).

Irrigation ratio

This is the ratio of currently irrigated area to irrigable command (nominal) area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinity/waterlogging, etc, could result in under utilization of land. On the other hand, cropping intensity, a ratio of annual cropped area to nominal area is indicative of annual land utilization. Burton et al. (2000) states that cropping intensities from 100 to 200% are considered good, while an inferior figure is low. Irrigation ratio is expressed as:

$$\text{Irrigation ratio} = \frac{\text{Irrigated area}}{\text{Command (nominal) area}} \quad (10)$$

Sustainability of irrigated area

This is the ratio of currently irrigated area to initially irrigated area when designed (Bos, 1997). It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation:

$$\text{Sustainability of irrigated area} = \frac{\text{Currently irrigated area}}{\text{Innitially irrigated area}} \quad (11)$$

Field survey

From October 2010 to February 2011, a comprehensive field survey was made to each scheme by a walk through the different components of the schemes. The objectives were:

i) To quickly get acquainted to the sources of irrigation water for these schemes;
ii) To physically assess and evaluate the water diversion head works;
iii) To understand the water conveyance and distribution systems and quickly evaluate their conditions;
iv) To understand the existing irrigation scheduling and operation of flow control structures;
v) To assess on-farm and off-farm irrigation water management practices.

Moreover, the field survey enabled measurement of some components such as dimensions of intakes, main canal sizes and tertiary offtakes. Field survey is of course an unavoidable activity in performance evaluation as it provides lots of information in a relatively short period of time.

Questionnaire survey

A questionnaire survey to water users themselves is a useful tool to collect primary data needed for performance assessment. In community-managed schemes, relevant data such as agricultural output, landholding, cropping pattern and intensity, degree of satisfaction with irrigation service, etc, are hardly available from secondary sources in Ethiopian cases. To this end, a structured interview was conducted at each irrigation scheme from October 2010 to February 2011 on sampled water users.

Flow measurement (Parshall flumes and stage-discharge relation)

Irrigation flow measurement is among key data for irrigation performance assessment. Measured irrigation flow data is not available at the schemes under consideration as this is given less priority. So diverted irrigation flow measurements were made for

Table 1. Meteorological data at Nura Era station (Golgota Scheme).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	22.2	23.0	24.7	25.5	27.0	27.8	25.5	25.0	25.4	23.7	21.5	20.8
Rainfall (mm)	35	12	57	41	26	32	139	140	46	39	5	11
Humidity (%)	56	56	56	56	48	46	58	63	60	48	50	54
Wind speed (km/d)	122	135	133	134	157	239	252	200	138	120	122	121
Sunshine (h)	8.8	8.5	8.2	7.4	9.0	7.4	6.9	7.3	7.5	8.7	8.7	8.8

Table 2. Meteorological data at Debre Zeit station (Wedecha Scheme).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	17.8	19.2	20.4	20.6	20.7	20.1	19.1	19.1	19.0	17.7	16.7	17.0
Rainfall (mm)	10	28	49	57	51	90	211	197	93	21	10	3
Humidity (%)	50	47	47	50	49	58	69	71	66	51	46	48
Wind speed (km/d)	169	194	196	194	193	125	111	127	107	178	192	197
Sunshine (h)	8.7	8.2	7.8	6.9	8.0	6.4	5.0	5.7	6.8	8.8	9.5	9.3

Table 3. Landholding characteristics of the schemes.

Scheme	Sub-system	Average landholding (ha)			
		Head reach	Middle reach	Tail reach	Average
Golgota		0.9	1.6	1.0	1.2
Wedecha	Godino	0.7	1.0	1.0	0.9
	Gohaworki	0.3	0.3	0.4	0.33

2010/2011 agricultural year (September 2010 to August 2011) for each scheme. For Wedecha Scheme (Godino and Gohaworki Sub-systems), flow measurements were made using Parshall flumes, with level readings made three times a day. However, for Golgota Scheme, an alternative method was used due to larger canal sizes. A staff gauge was use to measure water depths in the canal for different discharges being measured with current meters. A stage-discharge relation was used to determine flows for any other observed stages. The basic rating curve equation for open channel flow was employed to determine the constants k and m from a linear plot of h versus Q:

$$Q = k * (h - h_o)^m \tag{12}$$

Where, Q is discharge (m^3/s), h is stage in the canal (m), h_o is stage at which there is no flow (m) and k and m are constants.

The volume of diverted irrigation water to the irrigated fields at the outlet of the command area was also measured using the same methods for each scheme. This excludes the losses in the conveyance systems. Irrigation water being a major input, data on irrigation flow were used to evaluate both indicators of water supply and water productivity, which are key for comparative performance assessment.

Meteorological data

Climatic factors influence all the processes of water circulation and use and are mandatory. Meteorological stations are available nearby each irrigation scheme under consideration. For Godino and Gohaworki Sub-systems of Wedecha Scheme, data from the same station was used. Data includes temperature, rainfall, wind speed, humidity and sunshine hours. A summary of the meteorological data (monthly average values) at the two locations are given in Tables 1 and 2.

Landholding of farmers

Landholding is one of the factors constraining agricultural output particularly in smallholder irrigation schemes and affects land and water productivity. While in some schemes water is a limiting factor, in others, irrigable land becomes decisive. Average landholdings of farmers at head, middle and tail reaches of each scheme were determined using questionnaire survey. Ten randomly selected farmers were interviewed from each reach; that is, 30 for each scheme/sub-systems and totally 90 farmers interviewed (60 for two sub-systems of Wedecha Scheme). The landholding characteristics at these schemes are given in Table 3.

Irrigable and annual irrigated area

Irrigable land could either be fully or partly utilized for cropping throughout the year depending on various factors. Irrigable land is the size of land which could nominally be irrigated with the designed irrigation infrastructure. In this study, it was determined by surveying the areas with the global positioning system (GPS). Annual irrigated area is the sum of the areas under irrigated crops

Table 4. Annual irrigation water delivery per unit irrigated area.

Scheme	Sub system	Annual irrigated cropped area (ha)	Annual irrigation water delivery per unit irrigated cropped area, m^3/ha
Golgota		1,320	13,000
Wedecha	Godino	362	4,400
	Gohaworki	100	5,700

during all cropping seasons in a year and depends on irrigation intensity. It was determined using a questionnaire survey (irrigated land holding of sampled farmers and total number of farmers) in combination with secondary data compiled by local agricultural development offices.

Agricultural production (questionnaire)

Irrigation water management is ultimately meant to enhance agricultural production through sustainable water use. Secondary data on agricultural production is commonly ambiguous for research purposes and this data is better collected from primary sources. As such, with the campaign of questionnaire survey conducted during October 2010 through March 1011, data on yield was collected for 2007, 2008 and 2009 at each scheme. For this, sample farmers from head, middle and tail reaches were interviewed and from the average landholding and number of irrigators, total annual production was determined.

RESULTS AND DISCUSSION

Water supply indicators

Annual relative water supply (ARWS) and annual relative irrigation supply (ARIS) were evaluated for the agricultural year of 2010/2011 (September 2010 to August 2011) for each irrigation scheme. Annual values of four water supply/demand values were determined: namely, annual water supply, annual crop water demand, annual irrigation supply and annual irrigation demand. Annual irrigation supply is the volume of irrigation water delivered to the head of the command. Annual water supply is the sum of delivered irrigation water and effective rainfall. Annual crop water demand is the actual evapotranspiration demand of the crops, determined using FAO CROPWAT model for a given cropping pattern and irrigation intensity. Irrigation demand is crop water demand less effective rainfall. Water supply indicators for Golgota and the two sub-systems of Wedecha Scheme are given in Table 4 and Figure 2. From Figure 2, it can be observed that ARIS values are greater than ARWS values for each scheme, which indicates that irrigation is the major source of water supply for agriculture in the area. It can also be observed that the ARIS values for each scheme are higher than 1.0, depicting that, disregarding the distribution of the supply over the months, excess irrigation water is being supplied. It is interesting to note that more than three times of annual irrigation demand is being supplied for Golgota Scheme (ARIS = 3.17), followed by nearly twice of irrigation demand for Gohaworki Sub-system of Wedecha Scheme (ARIS = 1.90). Excess irrigation supply to Golgota Scheme is due to two important factors. First, it is the fact that farmers themselves are responsible for the volume of water diverted from the river; unlike Wedecha Scheme. As the diversion system for Golgota Scheme is temporary, the volume of water diverted into the canal depends on the stage of water in the river and is highly variable throughout the year. So, water is diverted without due consideration of demand and monthly variations of relative irrigation supply (RIS) are high. A permanent and still diversion structure would help to effectively regulate irrigation flows to respond to field demands during both high and low river stages. Secondly, an important factor for excess irrigation supply is the fact that there is no irrigation water fee at Golgota Scheme.

Farmers at Wedecha Scheme (Godino and Gohaworki Sub-systems) pay an annual irrigation water fee of about 60 US$/ha to a regional irrigation authority; contributing its part in saving irrigation water. However, farmers of Golgota Scheme have been using water for free since ever and as such there is no incentive for saving irrigation water. Introduction of water fee at Golgota Scheme is a feasible intervention for both as an incentive for saving precious water and for reducing future risks of waterlogging and salinity due to excess irrigation.

Godino and Gohaworki Sub-systems are being supplied with water from an embankment dam reservoir from which water is released through the main river channel using it as a conveyance system. Water release is controlled by a local irrigation agency and farmers can only have their requests. Excess irrigation supply to Gohaworki Sub-system (ARIS = 1.90) compared to Godino Sub-system (ARIS = 1.20) can be explained by the fact that the diversion structure of Gohaworki is located on the upstream; giving it advantage over Godino Sub-system. The sluice gates for regulating flows into the canals at both diversions have been demolished by farmers. Water level is being raised using locally available stones and wooden logs to facilitate diversion. Due to lack of control over the release of water, farmers at Gohaworki want to have as much irrigation water as possible diverted into their canals causing shortages to

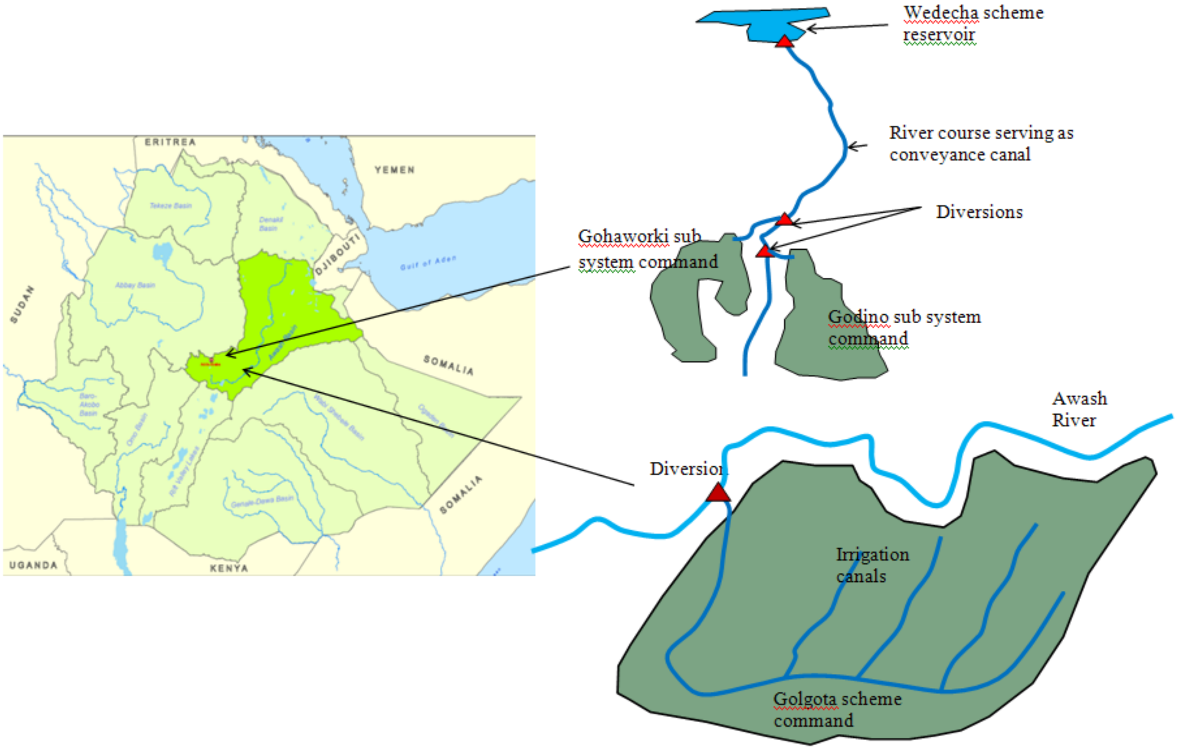

Figure 1. Location map of the irrigation schemes studied.

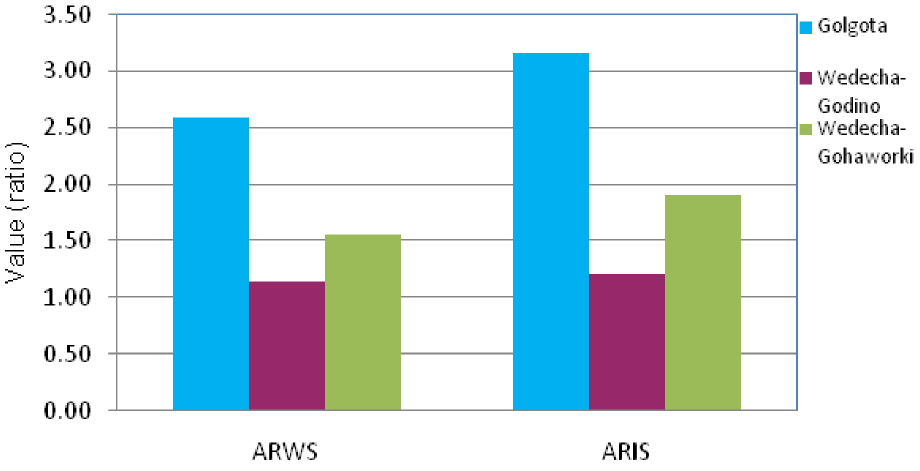

Figure 2. Annual water supply indicators.

Godino sub system; which is located on the downstream.

Agricultural output indicators

Land productivity

The output per unit of irrigated area or command area does not necessarily imply irrigation water supply conditions as there are other important factors affecting land productivity. However, land productivity and water productivity are interrelated in some way.

For the years 2007, 2008 and 2009, total agricultural production and thus outputs from the produce at local market prices (US$) were determined for each scheme. The size of irrigated cropped area and command area over those three years was more or less the same at each scheme. Cropping intensity at both sub-systems of Wedecha Scheme are 200%. At Golgota Scheme, only

Table 5. Irrigated/nominal command areas and annual agricultural output.

Scheme	Sub system	Irrigated cropped area (ha)	Nominal command area (ha)	Annual output (US$)
Golgota		1,320	600	3,520,000
Wedecha	Godino	362	300	913,000
	Gohaworki	100	60	165,000

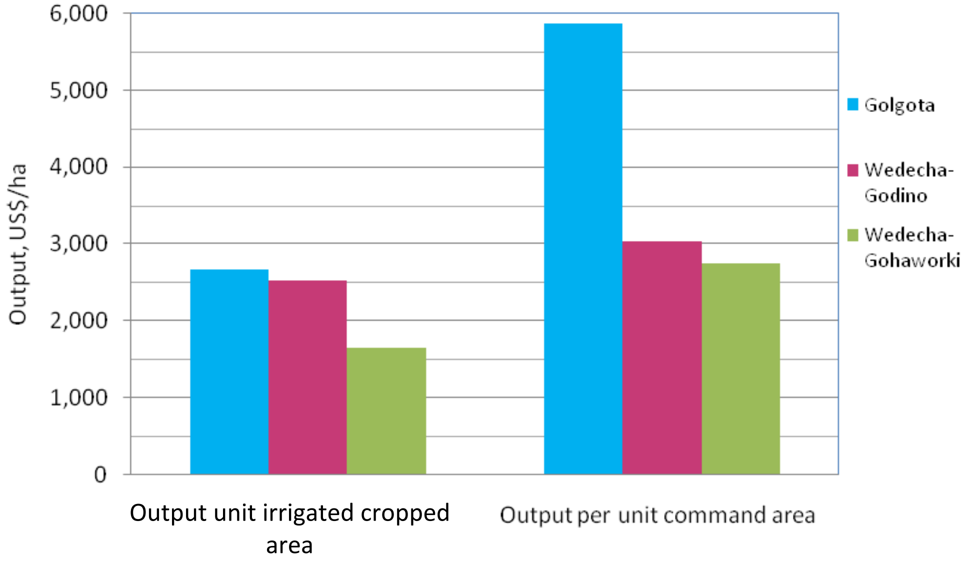

Figure 3. Land productivity indicators.

one crop (onion) is grown three times a year while the other crops are grown twice a year. The annual irrigated cropped areas were determined as the sum of the areas irrigated in two or three seasons during the year at each scheme. Irrigated and nominal areas and annual outputs are given in Table 5. Figure 3 shows that the output per unit command is higher than output per unit irrigated area for each scheme, implying that the irrigation intensity at each scheme is higher than 1.0. However, the output per unit command in case of Golgota Scheme is much higher than its output per unit irrigated area unlike the two sub-systems of Wedecha Scheme. So, it is evident that there is more intensive irrigation at Golgota thereby increasing the annual irrigated area in relation to the nominal command area. This is directly related to the responsibility over the diversion of irrigation water.

At Golgota, farmers are all responsible for the volume of irrigation water diverted; and this gives them the confidence that they could get the amount of water they need and thus, irrigate much more area of the command throughout the year. At Wedecha Scheme, farmers have little knowledge on the availability of irrigation water and leave their pieces of land un-irrigated. This is particularly apparent in the case of Godino Sub-system where the output per unit irrigated area and output per unit command are close. Being located on the downstream of Gohaworki, dependability of the flow is much lower for farmers of Godino Sub-system. This in turn results in relatively lower values of output per unit command in relation to the output per unit irrigated area. Cross comparison of output per unit irrigated cropped area depicts that Golgota Scheme and Godino Sub-system have very close and higher values than Gohaworki Sub-system. These higher values could be well explained by the following factors. Firstly, the average landholding size is 1.2 ha for Golgota and 0.9 and 0.3 ha for Godino and Gohaworki Sub-systems, respectively. When farmers get larger landholdings, they are willing to invest much more on their piece of land in terms of other agricultural inputs in addition to water; and more investment means better yield per unit of land. This was also confirmed during interviews with the farmers. Secondly, willingness by farmers to invest more is also related to their degree of confidence on water availability, which is much better in the case of Golgota even though it does not apply to Godino Sub-system. As a result, agricultural indicators perform much better for Golgota Scheme.

With average landholding of 0.3 ha at Gohaworki, the

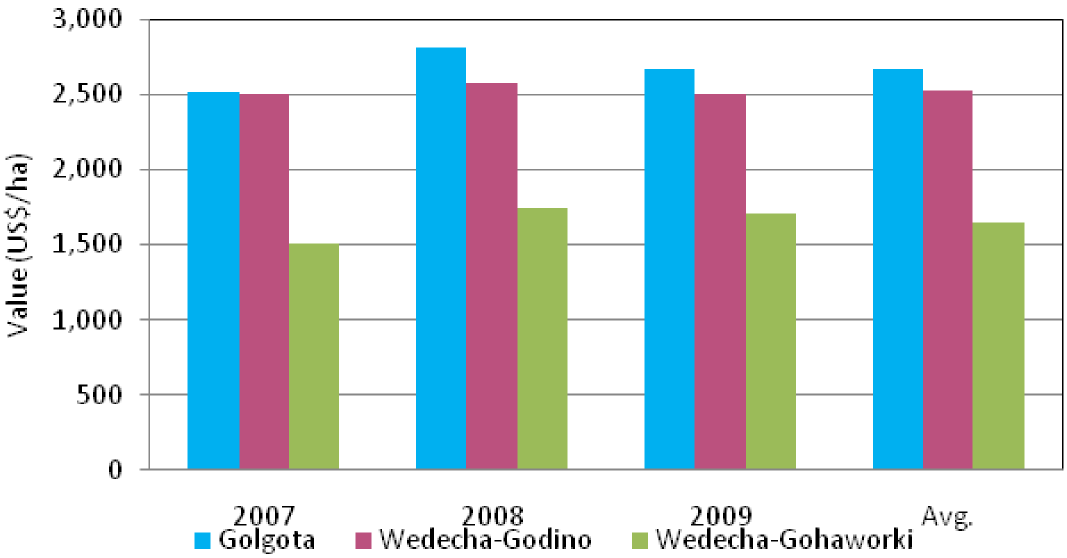

Figure 4. Output per unit irrigated cropped area (OPUIA) for three consecutive years.

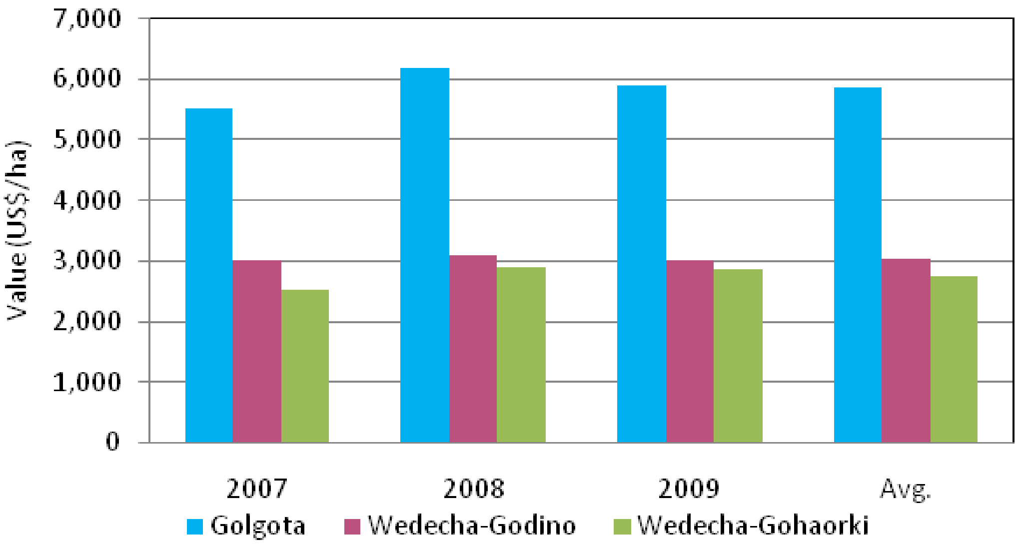

Figure 5. Output per unit command area (OPUCA) for three consecutive years.

With average landholding of 0.3 ha at Gohaworki, the average output per unit irrigated land area is only 1,650 US$/ha as compared to Golgota with a value of 2,660 US$/ha. It is also useful to consider land productivity indicators over consecutive years instead of average values. For this, with a base year of 2007 and annual inflation rate of about 10%, both OPUIA and OPUCA were calculated and shown in Figures 3 and 4. It is evident from the figures that the land productivity at each scheme is a little bit higher in 2008. Higher outputs are basically achieved under two conditions: either increase in yield or increase in the price of the produce or both. Availability of irrigation water also plays its own role; for instance at Golgota Scheme in 2009, there was an exceptionally low stage in the river and relatively it was a year of water stress which lowered the output. However, the variations of both OPUIA and OPUCA for each scheme over three years are not very significant as can be observed from Figures 4 and 5.

Water productivity

Water productivity values were evaluated for each

Table 6. Annual irrigation/water supply/delivery components.

Scheme	Sub system	Annual irrigation water supply (10^6) m^3	Annual irrigation water delivery (10^6) m^3	Annual total water supply (10^6) m^3	Annual water consumed (10^6) m^3
Golgota		28.71	17.22	30.70	7.43
Wedecha	Godino	2.67	1.60	3.32	1.98
	Gohaworki	0.96	0.57	1.15	0.49

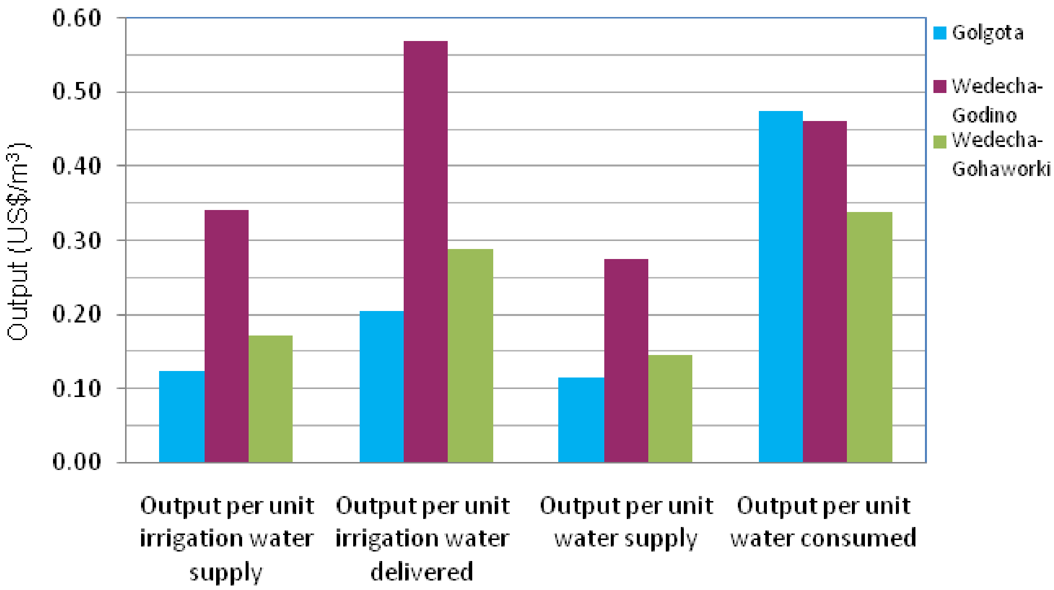

Figure 6. Water productivity indicators.

scheme using four different indicators: output per unit irrigation water diverted/supplied, output per unit irrigation water delivered to the command, output per unit water diverted/supplied and output per unit water consumed. For agricultural year of 2010/2011, all data were collected. The volumes of irrigation water diverted from the source were measured with Parshall flumes and stage-discharge relations. A similar methodology was used for delivered irrigation water at the head of the command areas. The consumed water (ET) is the actual crop evapotranspiration determined using FAO CROPWAT model version 8.0 (Swennenhuis, 2010). Irrigation/water supply/delivery components are given in Table 6. Figure 6 shows that the output per unit water consumed (OPUWC) is higher than all the other indicators of water productivity except for Godino Sub-system which has a higher output per unit irrigation water delivered (OPUID). For Golgota Scheme and Gohaworki Sub-system of Wedecha Scheme, it apparently implies that the volume of water consumed by ET is much less than the diverted/delivered irrigation/water supplies and indicates excess water/irrigation supply. Making a comparison between only output per unit water consumed (OPUWC) and output per unit irrigation water delivered (OPUID) for Golgota Scheme and Gohaworki Sub-system, greater values of the former indicator show that even the irrigation water alone delivered to command excluding rainfall is much more than total water demand.

Particularly for Golgota Scheme, one can compare OPUWC (0.47 US$/m^3) against OPUID (0.20 US$/m^3) implying that more than 55% of irrigation water delivered to the field is unproductive resulting in lower value of the later indicator. The output per unit irrigation water diverted/supplied (OPUIS) and OPUID for Godino Sub-system are more than twice of the corresponding values for Golgota Scheme and Gohaworki Sub-system. It implies that the value of irrigation water is higher for Godino implying more productive use of water while irrigation water is least productive at Golgota Scheme. Particularly considering Godino and Gohaworki Sub-systems being supplied from Wedecha Reservoir, lower outputs from diverted and delivered irrigation water for Gohaworki reveals excess water diversion because its diversion structure is located on the upstream of Godino. It also indicates that at Gohaworki Sub-system, there is a potential to increase the value of irrigation water by way

Table 7. Physical performance indicators (2007-2010).

Scheme	Sub-system	Irrigable land (ha)	Initial irrigated land (ha)	Currently irrigated land (ha)	Indicator	
					Irrigation ratio	Sustainability of irrigated area
Golgota		600	450	550	0.92	1.22
Wedecha	Godino	300	250	200	0.67	0.80
	Gohaworki	60	60	50	0.83	0.83

of saving water (matching supplies with demands). While lower values of indicators for OPUIS, OPUID and OPUWS could be attributed to water losses in conveyance, distribution and field application, output per unit water consumed (OPUWC) is not affected by water losses. This is due to the fact that consumed water is that which is being actually used by ET of the crops. Gohaworki Sub-system has the lowest value of OPUWC while Godino Sub-system and Golgota Scheme have higher values. Contributing factors are soil type, land suitability, crops grown, crop varieties, climate, agricultural inputs and impact of smaller landholding (at Gohaworki) discouraging farmers from investing more on their piece of land. Each consumed drop of water is most productive at Golgota Scheme. Generally, water productivity at Wedecha Scheme is much better than at Golgota Scheme, except OPUWC, which is a little bit higher for Golgota.

As was already stated, OPUWC is dependent on a set of complex elements of the farming system other than mere water management. Particularly for Godino Sub-system, water productivity is found to be higher not only in the region but also it is better as compared with schemes in other countries such as Hayrabolu, Turkey (Şener et al., 2007), Mahi Kadana, India; Saldana Colombia; Gorgo, Burkina Faso (Molden et al., 1998). So, Godino Sub-system water productivity indicators for OPUIS, OPUID and OPUWS could be benchmarked to other schemes in the region for saving irrigation water and for activities in enhancing water productivity. On the other hand, Golgota Scheme indicator for OPUWC could be used as a benchmark for water productivity improvement activities in the region through improvement of other crop and agricultural management practices in addition to water management.

Physical indicators

Data on three different sizes of land related to the schemes were collected to evaluate the physical indicators, that is, irrigable land, initially irrigated land and currently irrigated land. The irrigable land of each scheme/sub-system was determined by locating the boundary of the command area using GPS. These were then added to ArcGIS where the boundaries were plotted and the areas determined. The initial irrigated areas when each scheme was commissioned were taken from project reports and the same were confirmed from local irrigation agencies. However, data from design reports might not exactly imply the irrigated areas, because the whole designed area might not have been fully irrigated when the scheme was commissioned. Currently, irrigated areas for each scheme were determined in two ways. First, at each scheme, there is a list of irrigation water users along with their irrigated landholdings, complied by the schemes' water users associations. So, the irrigated area was found out as a sum of the irrigated holdings of all farmers belonging to the water users association. Secondly, with the boundaries of total irrigable command of each scheme potted, a survey was also conducted using GPS to determine non-irrigated lands, residential areas and grazing land. The net irrigated land area was then determined as the difference between total command area and sum of all non-irrigated land area within the command. The irrigated area at each scheme has remained the same over the years 2007 through 2010. Land areas pertaining to the schemes and indicators are given in Table 7.

Irrigation ratio, being an indicator for the degree of utilization of the available land for irrigated agriculture, could also be a useful indicator for whether there are factors contributing for under irrigation of the command area. Irrigation ratio is higher for Golgota Scheme with a value of 0.92 implying 92% of the irrigable command area is currently under irrigation followed by Gohaworki and Godino Sub-systems. Greater irrigation ratio at Golgota could be explained by three factors, namely, generous water availability, absence of irrigation water fee and better land productivity encouraging farmers to invest on more areas. Lower irrigation ratio at Godino Sub-system is attributed to lower reliability of irrigation flows during some months of the year, irrigation water fee charged by the regional irrigation authority and relatively lower land productivity compared to Golgota Scheme. Irrigation ratios in these schemes are much better compared to other schemes in Ethiopia. Şener et al. (2007) presented irrigation ratios for Hayrabolu irrigation scheme in Turkey over 16 years where the average value is 27%, in which case the schemes under the current study perform much

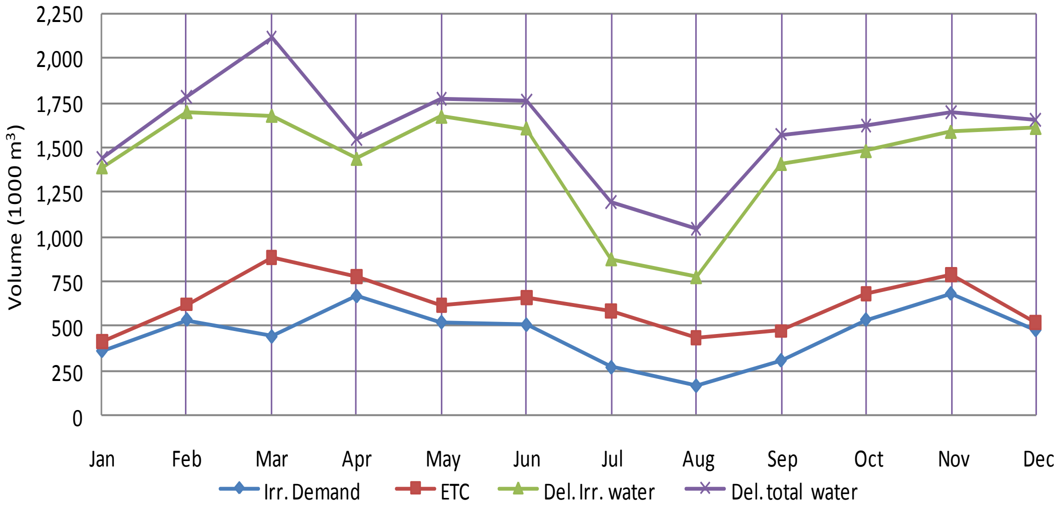

Figure 7. Monthly total water/irrigation supply/demand for Golgota Scheme.

better. Sustainability of irrigated area which tells on whether the area under irrigation is contracting or expanding right from the commencement of the scheme till date is a useful indicator for sustainability of irrigation. Godino and Gohaworki Sub-systems have more or less similar values, 0.80 and 0.83, respectively, implying reduction of irrigated areas by about 20%. For Golgota Scheme with a value of 1.22, the irrigated area has expanded by about 20% since commissioning.

Same reasons for irrigation ratio, namely, more reliability of irrigation water flow, absence of irrigation water fee and better land productivity are the contributing factors for the expansion. These factors encourage more farmers to come to the area and irrigate lands by leasing or renting from local land owners.

Monthly comparison of water supply indicators

Monthly water/irrigation supply/demand

While the annual water supply indicators are useful for aggregated water supply/demand of the scheme, they do not indicate the specific periods in a year with excess/ shortage of water/irrigation supply. So for each scheme, monthly values of irrigation/water supply/demand were determined for monthly indicators. Monthly water demands are ET values. It was determined based on climate data, cropping pattern and crop data using FAO CROPWAT 8.0 for each scheme. Monthly irrigation demands for the schemes were also determined using FAO CRPWAT 8.0 as a difference between monthly water demand and effective rainfall. Monthly irrigation supplies were determined by continuous flow measurement of irrigation water delivery at the inlets of the command area using Parshall flumes or stage-discharge relations. Monthly water supplies are then determined as the sum of monthly irrigation supplies and effective rainfall. The monthly water/irrigation supply/demand components and indicators are given in Figures 7 through 12. It is observed from Figure 8 that for Golgota Scheme the monthly RIS are higher than RWS for all months; which implies that the vast majority of excess supply comes from irrigation. Moreover, it is evident from the figure that the RIS values are variable throughout the year. This confirms that irrigation water diversion at Golgota is based on stage of water in the river and does not well address demands. All RIS being higher than 2.0, though it indicates excess water supply throughout the year, exceptionally high irrigation supplies occur during the months of August, September, January and March. There is significant amount of rainfall during July, August September, and the river stage is high. While there is practically very little irrigation demand during these months, farmers still divert water and it is released at the tail end of the command.

Similarly, farmers keep on diverting water during off irrigation periods where the field demand significantly falls, which intermittently leads to high RIS. For Wedecha Scheme (Godino Sub-system) (Figure 10), monthly RWS and RIS are closer to each other with the exception of the months of July, August and September where RIS are extremely high. At this scheme more than 60% of the annual rainfall occurs during these three months and there is practically no irrigation demand, which results in high RIS. The RIS also tends to be higher during February to April which is the minor rainy season of the area. It is also worth to see that unlike the fact that annual RIS and RWS values are higher than 1.0, there occurs water stress during the dry months of November to January and May where both monthly indicators are lower than 1.0. The monthly values of indicators for

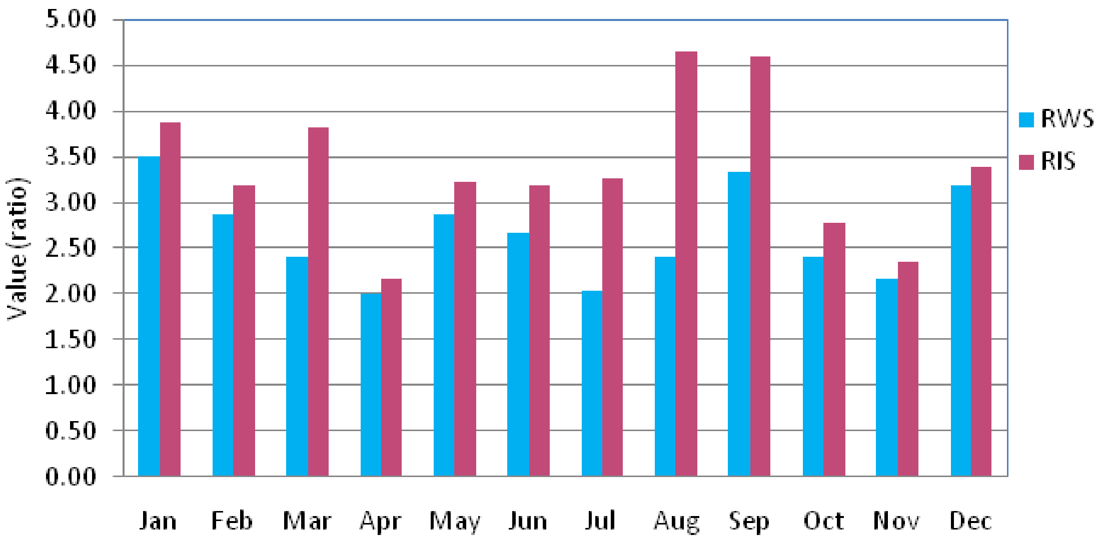

Figure 8. Monthly water supply indicators for Golgota Scheme (2010/2011).

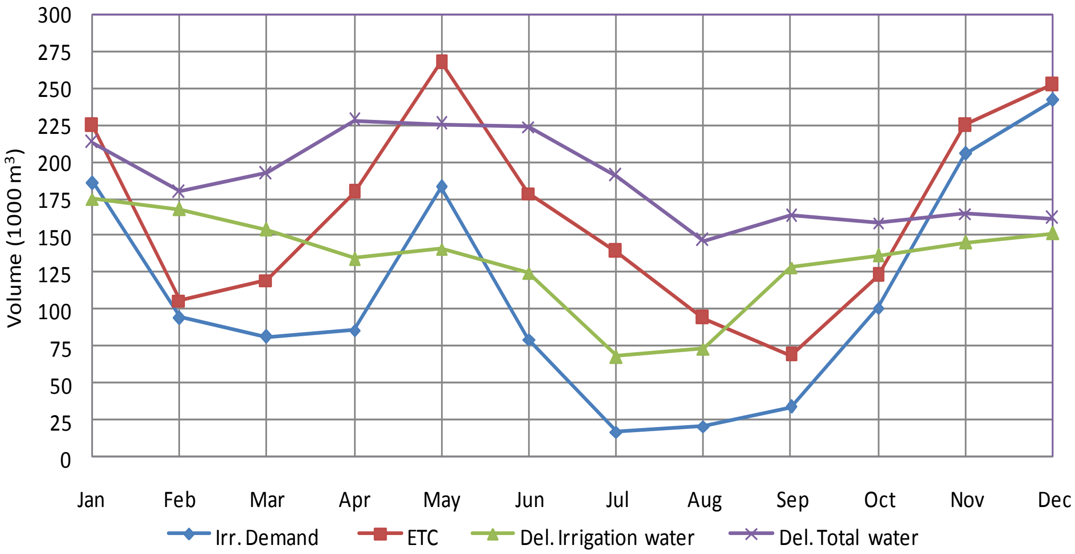

Figure 9. Monthly total water/irrigation supply/demand for Wedecha (Godino Sub-system).

Gohaworki Sub-system (Figure 12) are also variable throughout the year. However, unlike Godino, for Gohaworki, both indicators are higher than 1.0 for each month which depicts demands are met throughout the year. The RIS is much higher during the main rainy months of July to September due to little irrigation demand. Relatively, higher values of indicators were also observed during January to March.

The fact that Gohaworki Sub-system diversion structure is located on the upstream of Godino enables it to deliver supplies sufficient to meet demands throughout the year. However, at both sub-systems, matching supplies with field demands is the main concern to flatten the monthly fluctuation of water supply indicators thereby saving irrigation water lost during off-irrigation months and due to excess supply during irrigation months.

Conclusion

Though, there are some studies on application of external indicators on individual schemes in Ethiopia, there are only few studies on their application for cross-comparison of schemes for continuous improvement. Comparative

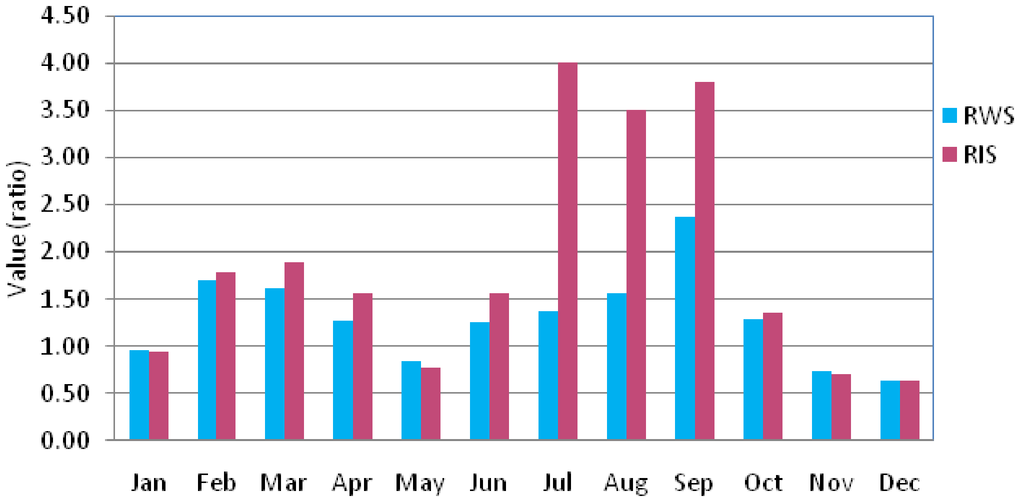

Figure 10. Monthly water supply indicators for Wedecha (Godino Sub-system) (2010/2011).

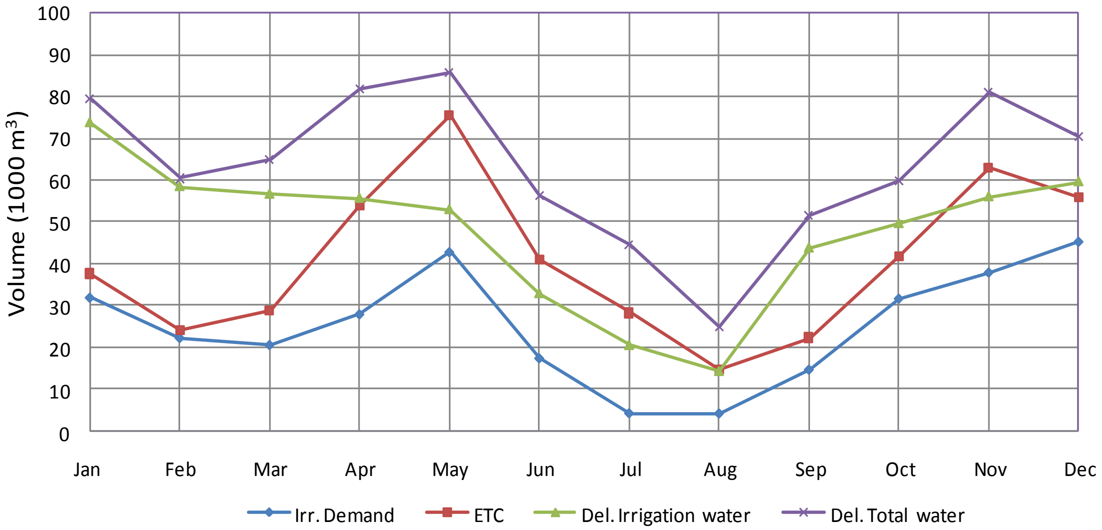

Figure 11. Monthly total water/irrigation supply/demand for Wedecha Scheme (Gohaworki Sub-system).

indicators are more useful when used for comparison whereby better performances of one scheme could be benchmarked to others. This study will assist efforts towards enhancing productivity and sustainable use of irrigation water in community-managed schemes in the region. Regarding the water supply, considering annual values, Golgota and Gohaworki Sub-systems deliver nearly 3 and 2 times the actual irrigation demands as confirmed by ARIS, while for Godino Sub-system (ARIS = 1.20) is nearly acceptable. This is because particularly at Golgota, farmers are responsible for overall water management. It indicates that overall management by farmers alone is not a preferable model as long as water productivity is concerned. Dual management consisting of a local irrigation agency for monitoring the volume of water diverted and introducing a reasonable irrigation water fee would help to discourage excess irrigation diversions. For Gohaworki Sub-system, diversion is on upstream of Godino Sub-system giving farmers the advantage of taking excess water. Control sluice gates at both diversions are demolished; re-installation of these gates at both Gohaworki and Godino Sub-system intakes and monitoring mechanisms for gate operation would help for each scheme to get its share of water. Higher output per unit irrigated area for Golgota Scheme shows that farmers invest more on their lands when reliability of water is high and when they get larger landholding. Higher values of the same for Godino Sub-system are attributed to better investments by farmers due to larger landholding. On the other hand, exceptionally high output

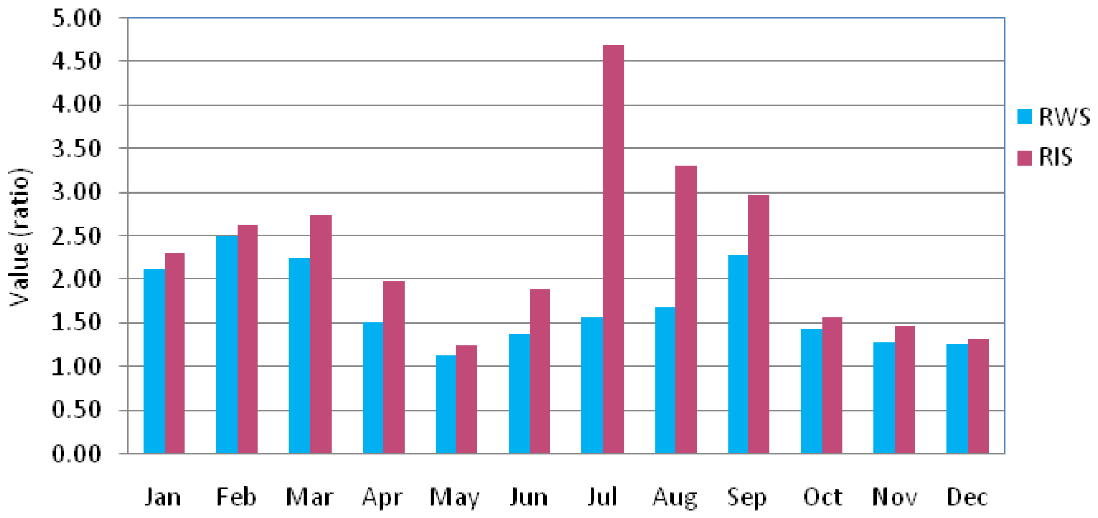

Figure 12. Monthly water supply indicators for Wedecha Scheme (Gohaworki Sub-system) (2010/2011).

per unit command for Golgota Scheme is due to more intensive irrigation, which is linked to more reliable irrigation water for free. In terms of both OPUIA and OPUCA, Golgota Scheme could be used as a benchmark in the region.

Godino Sub-system of Wedecha Scheme has better water productivity because water is released by government agency and farmers make wise use of it. It is a good example to be benchmarked in the region for water productivity improvement activities. Irrigation ratio as a physical indicator showed that more areas of the command are irrigated when irrigation water supply is reliable as had been depicted at Golgota Scheme and Gohaworki sub-system. Expansions or contractions of irrigated areas are also attributed to water management responsibilities and reliability of irrigation water supply. This was confirmed by a contraction of area at Wedecha Scheme (both sub-systems) by about 20% and expansion by about 20% at Golgota Scheme. Reasons for expansion at Golgota are excess availability of water and overall management by the farmers themselves, driving more farmers into the area.

REFERENCES

Awulachew SB, Merrey DJ (2006). Assessment of small scale irrigation and water harvesting in Ethiopian agricultural development. In 2nd Regional Workshop on agricultural water management in Eastern and Southern Africa Maputo, Mozambique: ASARECA.

Awulachew SB, Yilma AD, Loulseged M, Loiskandl W, Ayana M, Alamirew T (2007).Water resources and irrigation development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute.

Bos MG (1997). Performance indicators for irrigation and drainage. Irrig. Drain. Syst. 11:119-137.

Burt CM, Styles SW (1999).Modern Water Control and Management Practices in Irrigation- Impact on Performance. Vol. Water Report #19Rome, Italy: FAO.

Burton M, Molden D, Skutsch J (2000). Benchmarking irrigation and drainage system performance: Working group on performance indicators and benchmarking. Rome, Italy: FAO.

FAO (2003).The irrigation challenge- Increasing irrigation contribution to food security through higher water productivity. Issue Paper 4Rome, Italy: IPTRID Secretariat.

FAO (2005). Aquastat- Information system on water and agriculture. In Water report no.29 Rome, Italy.

Ghosh S, Singh R, Kundu DK (2005). Evaluation of Irrigation-Service utility from the perspective of farmers. Water Res. Manage. 19:467-482.

Hedayat (2005).Improving the performance of water delivery in the Dez and Moghan Irrigation Scemes in Iran. In PhD Thesis Cranfield University, UK.

Kloezen WH, Garcés-Restrepo C (1998). Assessing irrigation performance with comparative indicators: The case of the Alto Rio Lerma Irrigation District, Mexico. Vol. Research Report 22 Colombo, Sri Lanka: International Water Management Institute.

Kuscu H, Demir AO, Korukcu A (2008). An assessment of the irrigation management transfer programme: Case study in the Mustafakemalpasa irrigation scheme in Turkey. Irrigation and Drainage 57:15-22.

Malano H, Burton M (2001). Guidelines for benchmarking performance in the irrigation and drainage sector. Rome, Italy: Food and Agriculture Organization of the United Nations.

Malano H, Burton M, Makin I (2004). Benchmarking performance in the irrigation and drainage sector: A tool for change. Irrig. Drain. 53:119–133.

Molden D, Sakthivadivel R, Perry CJ, Fraiture CD, Kloezen WH (1998).Indicators for comparing performance of irrigated agricultural systems. Vol. Research Report 20 Colombo, Sri Lanka: International Water Management Institute.

MoWR (2004). National water development report for Ethiopia. Addis Ababa, Ethiopia: Ministry of Water Resources.

Plusqellec H (2009). Modernization of large scale irrigation systems: Is it an achievable objective or a lost cause? Irrig. Drain. 58:104-120.

Şener M, Yüksel AN, Konukcu F (2007). Evaluation of Hayrabolu irrigation scheme in Turkey using comparetive performance indicators. J. Tekirdag Agric. Fac. pp. 1-4.

Swennenhuis J (2010). FAO CROPWAT 8.0, Water Resources Development and Management Service Rome, Italy.