Comparison of irrigation performance based on management and cropping types

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Abstract

Although performance evaluation of irrigated agriculture has gained momentum since late 1980s worldwide such attempt is rarely carried out in Ethiopia. The aim of this study was to assess the performance of 7 irrigation schemes some of which are expected to contribute much to the national economy. Sugar cane is grown by three of these schemes whereas cotton is grown by three schemes and the remaining single scheme grows tobacco. With regards to management types both government agency and community managed schemes are considered. The scheme level values of water supply performance indicators show that there was no constraint of water availability and supply at scheme level. In general, schemes that grow sugar cane were found to have attained higher outputs per units of land and water used which ranges from 7794 – 10834US$/ha and 0.24 – 0.55 US$/m^3 respectively. On the other hand, whether state farm or community managed, schemes that grow cotton have shown low output per units of land and water, i.e. 310 – 385 US$/ha and 0.01 – 0.05 US$/m^3 respectively. Large productivity performance differences have been observed between irrigation schemes with same cropping and management types. From scheme level performance values it is not simple to identify the area where and what is going wrong which is responsible for low performance. Generally, problems casing low productivity derive both in management and deterioration of physical structures. Hence investment on improvements of physical structures, management and operation of the system at all levels will bring substantial improvement in the performances of cotton producing schemes.

1. Introduction

Irrigation is highly expected to play a major role in the realization of Ethiopian food security and poverty alleviation strategy. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops. From this important viewpoint irrigation projects are widely studied, planed and implemented throughout the country. However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Whether traditional or modern, public agency or community managed many of the existing irrigation systems are deteriorating in their physical structures, operation and management.

Performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify 'why the scheme is performing so' which in turn imply means of improvement. Of course performance evaluation needs relevant and reliable data which is rarely measured in Ethiopia.

According to Clemmens, A.J. and Molden. D.J. (2007) two major approaches to performance evaluation are to consider, how well service is being delivered and the outcomes of irrigation in terms of efficiency and productivity of recourses use. To measure these performances a number of indicators have been proposed and tested in different parts of the world (Molden, D. et al. 1998; Kloezen W.H., 1998; Burton, M. et al. 2000; Lorite, J. et al. 2004, Bos, M.G. et al. 2005, Vandersypen et al., 2006). IWMI's minimum sets of performance indicators were used by many researchers to compare different irrigation schemes. Comparison helps to identify 'who is doing what right' and what lesson can be learnt or who can be a benchmark for a particular activity. The objective of this study was to assess the performance of 7 irrigation schemes in Ethiopia based on management and cropping types using IWMI's performance indicators.

2. Technical background on performance assessment

Performance can be simply defined as "the level of achievement of desired objectives" (Mohtadullah, K., 1993). Indicators are used to measure performance. An indicator is some number that describes the level of actual achievement in respect of one of the objective of irrigation system. Indicators are used to simplify the otherwise complex internal and external factors affecting the performance of irrigated agricultural system. Performance can be measured from process and output points of view. Process measures of performance relate to a system's internal operations and procedures whereas output measures of performance examine the quality and quantity of the system's final output (Small, L. and M. Svendsen, 1990). While quoting the value of certain indicators, at a particular irrigation system and time, it means that all other factors and processes are ignored or neglected. The fact that an indicator services as a guideline for further decision making it should be carefully chosen, measured and interpreted.

Irrigation performance, whether bad or good, is the result of verities of activities such as planning, design, construction, operation of facilities, maintenance and proper application of irrigation water and agronomic activities (Small L. and Svendsen M. 1990). Facilitation and execution of these activities requires proper coordination of six functional processes of irrigation, i.e. personnel management and support, equipment management, financial management and accounting, and resources mobilization. Planning, design and construction of irrigation schemes are mainly dealing with creation of physical infrastructure to facilitate the capturing of water from its source and transportation up to the farm level. These physical facilities need to be properly operated to ensure the capturing, allocation and delivery of water at the right time and adequate quantity. Maintenance activities are designed to ensure the capabilities of physical infrastructure to deliver the intended amount of water over the project life time. Application of water to the field is the core activity of irrigation which is designed to disperse the incoming stream from higher level canal over the field thereby storing in the crop root zones. Substantial improvements in the performance of such a complex system is not possible by making big improvements at only one level within the system (Clemmens A.J. & Molden D.J., 2007). Physical or management improvements may need to be made at all levels before substantial improvements in the performance can result.

Gorantiwar S.D. and I.K. Smout (2005) have summarized performance measures proposed by various researches into allocation type and scheduling types. Allocation types performance measures are those which need to be attained primarily during the allocation of the resources at the planning and operation stages. Productivity and equity are performance measures under allocation type category. Scheduling type performance measures consists of irrigation scheduling, i.e. temporal and spatial distribution of irrigation water to the users. This measures adequacy, reliability, flexibility, efficiency and sustainability.

Scheduling should be such that water deliveries need to be adequate both in planning and operation, reliable, flexible and sustainable. The same authors grouped these two categories of performance measures into: economic (productivity), social (equity), environmental (sustainability) and management (reliability, adequacy, efficiency and flexibility).
Conveyance efficiency is used to compare the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water delivered into the irrigation scheme. Its measurement is important in that water allocation plans are developed using estimated efficiencies of water flow at various stages and time. Deterioration of efficiency over the years will reduce the performance of the irrigation scheme over this period. Gorantiwar and I.K. Smout (2005) categorized the importance of efficiency in two ways: Firstly, appropriate optimum allocation plans cannot be developed if proper consideration is not given to efficiency. Inaccurate or simplified estimates also have a major influence on other performance parameters such as productivity, adequacy, equity and reliability. Secondly, the inspection of efficiencies over space and time at different levels enables the irrigation authorities to learn which part of the scheme is inefficient, where it is inefficient and how it is deteriorating.

Productivity is related to output from the system in response to the input added to the system and there are several indicators of productivity. The primarily output of the scheme is the total crop yield or its economic equivalence per units of land or water used. Hence, most often the productivity is expressed in terms of land or water supplied to produce a certain level of output. Water productivity deals with the amount of production (mass or monetary equivalent) per water supplied to the scheme during the season. Land productivity on the other hand is production per unit of land cultivated.

3. Materials and Methods

3.1. Description of the schemes

This study uses six government owned irrigation schemes for detail investigations which are believed to have large contribution to national income and one community managed irrigation schemes. The schemes are geographically located in south, east and central parts of the country. Table 2 gives brief information on the schemes. For details on the characteristics of the schemes, see Girma and Awulachew (2007).

3.2. Performance indicators

The performance indicators adopted in this study are:

1. ***Irrigation water delivery performance***
    a. Conveyance efficiency (E_C)
    b. Annual relative water supply (ARWS)
    c. Annual relative irrigation supply (ARIS)
    d. Water delivery performance or water delivery ration (WDR)

2. ***Output performance indicators***
    a. Output per harvested area (tons/ha)
    b. Output per harvested area (US$/ha)
    c. Output per command area (US$/ha)
    d. Output per water supplied (US$/m^3)

These indicators were measured using the following mathematical descriptions:

$$E_C = \frac{Water\ flowing\ out\ of\ the\ system}{Water\ flowing\ into\ the\ system} \tag{1a}$$

$$ARWS = \frac{Total\ volume\ of\ water\ supplied}{Total\ volume\ of\ crop\ water\ demand} \tag{1b}$$

$$ARIS = \frac{Total\ volume\ of\ irrigation\ water\ diverted}{Total\ volume\ of\ irrigation\ water\ demanded} \tag{1c}$$

$$WDR = \frac{Volume\ of\ water\ actually\ delivered}{intended\ volume\ of\ water\ to\ be\ delivered} \tag{1d}$$

$$Outpout\ per\ harvested\ area\,(tons/ha) = \frac{Production\,(tons)}{Irrigated\ cropped\ area\,(ha)} \tag{2a}$$

$$Outpout\ per\ harvested\ area\,(US\$/ha) = \frac{Local\ value\ of\ production\,(US\$)}{Irrigated\ cropped\ area\,(ha)} \tag{2b}$$

$$Outpout\ per\ command\ area\,(US\$/ha) = \frac{Local\ value\ of\ Production\,(US\$)}{Command\ area\,(ha)} \tag{2c}$$

$$Outpout\ per\ water\ supplied\ (US\$/m^3) = \frac{Local\ value\ of\ Production\,(US\$)}{Diverted\ irrigation\ supply\,(m^3)} \tag{2d}$$

Data used in this study are emanating from different sources. Sugar estates have their own records regarding annual production, water diverted to the schemes and meteorological data.

Table 1: Sources of important data

Data	Irrigation schemes					
	Metahara	Wonji	Finchaa	Hare	Sille	Bilate
Metro Data	Estate	Estate	Estate	NMSA	NMSA	Tessema, 2006
Production	Estate	Estate	Estate	Belete, 2006	Aklilu, 2006	Tessema
Water supply	Estate	Estate	Estate	Belete	Aklilu	
ARWS	calculated	calculated	calculated	Belete	Aklilu	Tessema
ARIS	calculated	calculated	calculated	Belete	Aklilu	Tessema
Efficiency	measured	measured		Belete	Aklilu	

Table 2: Characterization of selected irrigation schemes

Scheme name	**Hare**	**Sille**	**Bilate**	**Metahara**	**Wonji**	**Finchaa**
Latitude	6º 30´ to 6 º 38´ N	5º 49' to 5º 55' N	$6^0$48' to $6^0$50'N	8º 21' to 8º 29' N	8º 21' to 8º 29' N	9º 30' to 9º 60' N
Longitude	37 º 33´ to 37º 37´ E	37º 26' to 37º 29' E	$38^0$4' to $38^0$5' E	39º 12' to 39º 18' E	39º 12' to 39º 18' E	37º 10' to 37º 30' E
Average annual rainfall (mm)	830.7	748	734	659.6	832	1300
Average annual ET_o (mm)	1651.2	1540		1958	1596.5	
Predominant soil types	Sandy loam to clay soil	Silty loam and clay loam	Sandy to loam	Sand to clay loam	Clay, light soil	black heavy clay
Water source	Hare River	Sille River	Bilate River	Awash River	Awash River	Finchaa River
Water availability	Scarce in some periods	Scarce in some periods	sufficient	abundant	abundant	abundant
Irrigated area (ha)	1962	1082	870	11058	7279.8	8500
Main crops	Banana, cotton, maize, fruit trees, sweet potato, vegetables	Banana, cotton, maize	Tobacco, maize	Sugar cane	Sugar cane	Sugar cane, horticultural crops
Year first operational	1996	1957	1962	1966	1954	1991
Type of management	community	government	Government/ private	government	government	government
Land ownership	private	government	Government	government	government	government
Method of water abstraction	Gravity (inundation, weir)	Gravity (inundation)	Gravity (barrage)	Gravity (weir)	Pump	Gravity/ weir
Water delivery infrastructure	Open channel	Open channel	Open channel/ pipelines	Open channel	Open channel	Open channel/pipe
Predominant on-farm water application method	Furrow, basin	Furrow, basin	furrow	furrow	Furrow	Sprinkler/ furrow

4. Results and Discussions

4.1. Water delivery performance

Water delivery performances considered are conveyance efficiency, annual relative water supply, and annual relative irrigation supply and water delivery ratio. The results of conveyance efficiency measurements given in Fig. 1 show that there is a high water loss especially in community managed Hare irrigation scheme. Through filed measurements it was evidenced that the canal losses more than 50% of water over 5 km canal distance from the diversion point. As the physical conditions of canal in Hare irrigation scheme is bad, the losses are mainly attributed to seepage from the canals. Moreover, even if they are closed, points of unauthorized water turnouts contribute also to low conveyance efficiency because of leakages.

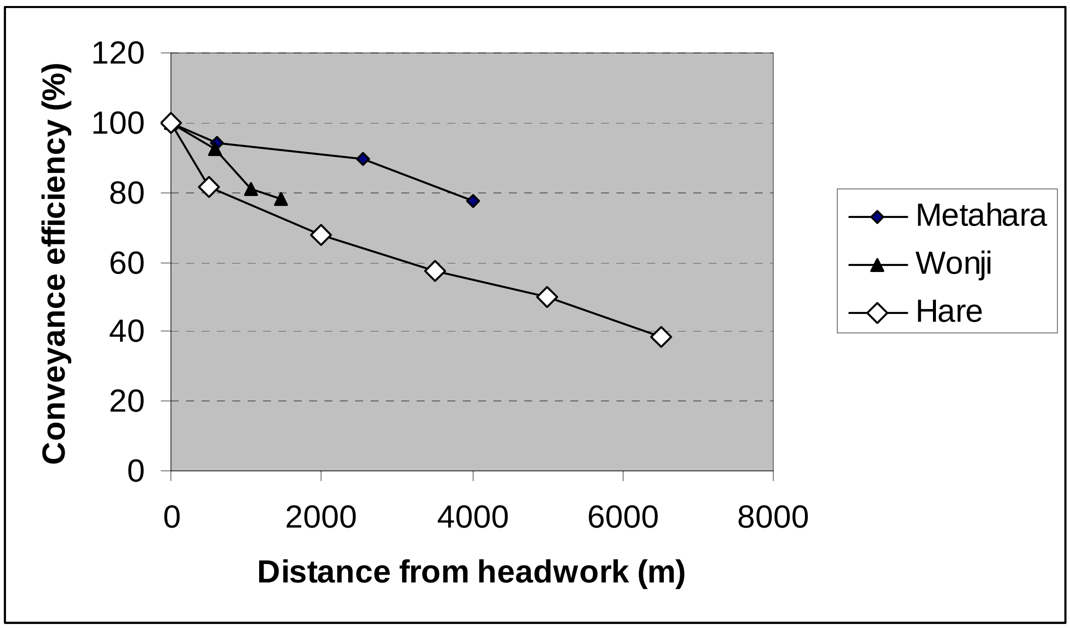

Fig. 1: Variation of conveyance efficiency along the canals of some schemes

Conveyance efficiency underlies spatial variations based on the conditions of the canal and management system. Farm units which are located along the canal segment with low conveyance efficiency tend to suffer from unreliable and untimely supply of water.

These problems have been observed in community managed irrigation schemes such as in Hare. To this effect, farmers located at tail-end of the canal (>7km) are limited in their crop diversification and forced to grow relatively water stress resistant crops such as cotton and sweet potato. Not only bad conditions of physical structures but also leakage through unofficial points of water turnouts are observed to be reasons for rapid decline of conveyance efficiency in Hare irrigation schemes

Previous studies in Wonji indicated that seepage losses in the tertiary canals account to about 40% and contributed to rising of groundwater level to 0.94m below the surface (Habib, 2005).

The values of water delivery performance, i.e. annual relative water supply (ARWS) and annual relative irrigation supply (ARIS) are given in table 3. These indicators are evaluated as optimal if their values would be equal to one. Less or greater than one would mean under or over supply of water respectively. ARWS relates the total volume of water applied (irrigation plus total rainfall) to the volume of water required by the crops. It can also be used both as a measure of adequacy and seasonal timelines (Levine 1982 and Meinzen D., 1995, In: Kloezen W.H & G.-R. Carlos, 1998).

The annual relative irrigation supply (ARIS) on the other hand is the ratio of the volume of irrigation water delivered to the volume of irrigation water demanded (net irrigation water requirement). It indicates also the extent to which the water supplied was adequate to satisfy the water demand. The value of this indicator is nearly unity in Wonji irrigation scheme and range from 1.46 to 2.05 incase of other schemes indicating that the amount of water supplied at scheme level exceeded the estimated crop water requirement.

Table 3: Values of water delivery performance indicators (2005/06)

Scheme name	Values of water supply performance		
	ARWS	**ARIS**	**WDR**
Hare	1.22	2.05	1.07
Sille	1.66	1.46	0.95
Bilate	1.86	2.00	1.30
Metahara	1.45	1.59	1.03
Wonji	1.11	0.95	0.62

The water delivery ration (WDR) is an indicator that relates the amount of water delivered to the amount of water needed to be delivered, i.e. total water supplied to the scheme divided by gross irrigation water requirement. According to the values of this indicator, Wonji and Sille irrigation schemes were found to have delivered less amount of water than theoretically forecasted. Wonji scheme is characterized by lower values of all water supply and delivery performance indicators compared to other schemes. The cost involved in pump diversion might have contributed to efficiency of resources use in Wonji

4.2. Production per unit area

Values of crop production per units of harvested land in the studied irrigation schemes are presented in Table 4 and figures 2-4. As can be seen from table 4, production varies from 122 to 174 tons per hectare in sugar cane producing irrigation schemes and from 0.50 to 3.56 tons per hectare in cotton producing schemes. The productivity of tobacco varied between 0.45 to 1.55 tons per hectare. The average sugar cane production in Metahara, Wonji and Finchaa is respectively 162.3, 147.1 and 136.5 tons per hectare. This shows that Metahara has produced more cane per units of area.
With a standard deviation of 13.7, the productivity variation is higher in Finchaa followed by Metahara and Wonji sugar estates. Huge differences between minimum and maximum productions in table 4 show inconsistencies that exist in the management practices as well as practically attainable level of productivity under the existed condition. Compared to sugar cane producing schemes, large coefficients of variation (Cv) in cases of cotton and tobacco producing schemes have been observed indicating high productivity variation from year to year. The reasons could be inconsistencies in the agricultural practices, management system and input supplies.

Table 4: Output per units of harvested land (from 1998/99 – 2005/06 except for Hare scheme)

Scheme name	Crop grown	productivity (tons/ha)				Cv (%)
		minimum	maximum	mean	SD	
Metahara	Sugar cane	152.6	173.8	162.3	9.3	5.6
Wonji	Sugar cane	137.2	152.8	148.1	5.6	3.4
Finchaa	Sugar cane	123.5	169.0	138.3	13.4	9.7
Average (sugar cane)		137.2	165.2	148.6	9.52	6.5
Hare[1]	Cotton	0.70	2.20	1.30	0.65	50
Sille	Cotton	0.50	2.40	1.09	0.79	72
M. Sedi	Cotton	1.57	3.56	2.51	0.67	26.7
Average (cotton)		0.92	2.72	1.67	0.65	43
Bilate	Tobacco	0.47	1.55	0.90	0.33	36.9

1. Compared between different villages in the scheme

The productivity of cotton presented in this study, when compared to the optimum yield, i.e. 5.4 tons/ha (Aklilu, 2006), it is evident that there is a room for improvement. Melka Sedi was found to perform better than other cotton producing farms.

To compare the outputs of schemes and productivity of different crops per units of land and water supplied, monetary equivalents of the production during the season 2005/06 have been considered. This type of calculation was made taking into account the farm gate unit price of sugar, cotton and tobacco in the year 2005/06 as 491.2, 1069.77 and 1962.79 US$ per tons respectively. The results presented in figures 2 and 6 show that outputs per units of land and water are by far large in sugar producing schemes than cotton and tobacco farming schemes.

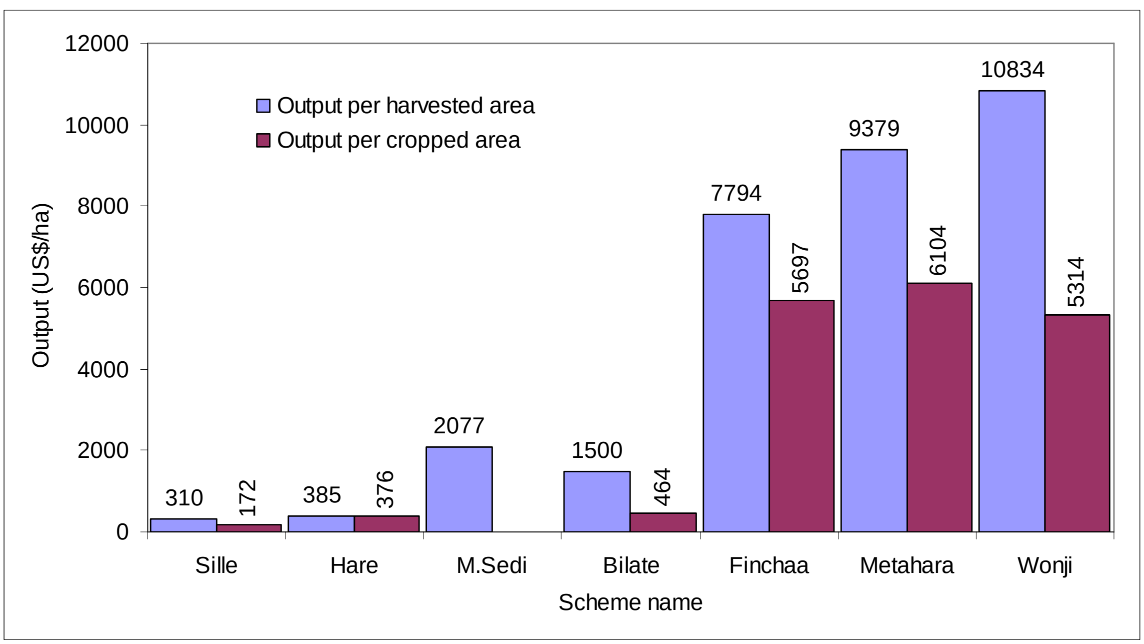

Fig. 2: Output per units of harvested and irrigable area (2005/06)

The difference between schemes in terms of output per irrigable area is less compared to output per harvested area. In the year 2005/06, the proportions of harvested to total cultivated area in Wonji, Metahara and Finchaa are 49, 65 and 73% respectively.

Even if the cane production per harvested area in 2005/06 was higher in Metahara (Fig. 4) than other cane producing schemes output per units of harvested land (US$/ha) was higher in case of Wonji than Metahara (Fig. 2). This is because the end sugar productivity was higher in Wonji than others, i.e. 21.92, 15.98 and 15.77 tons of sugar per hectare of harvested area respectively in Wonji, Metahara and Finchaa. Sugar produced per hectare per month was also greater in Wonji followed by Metahara and Finchaa which may be attributed to the differences in the cutting ages of the cane.

Fig. 3 shows the relationships between the size of area harvested and the corresponding cane production during the last 8 years (1998/99 – 2005/06).

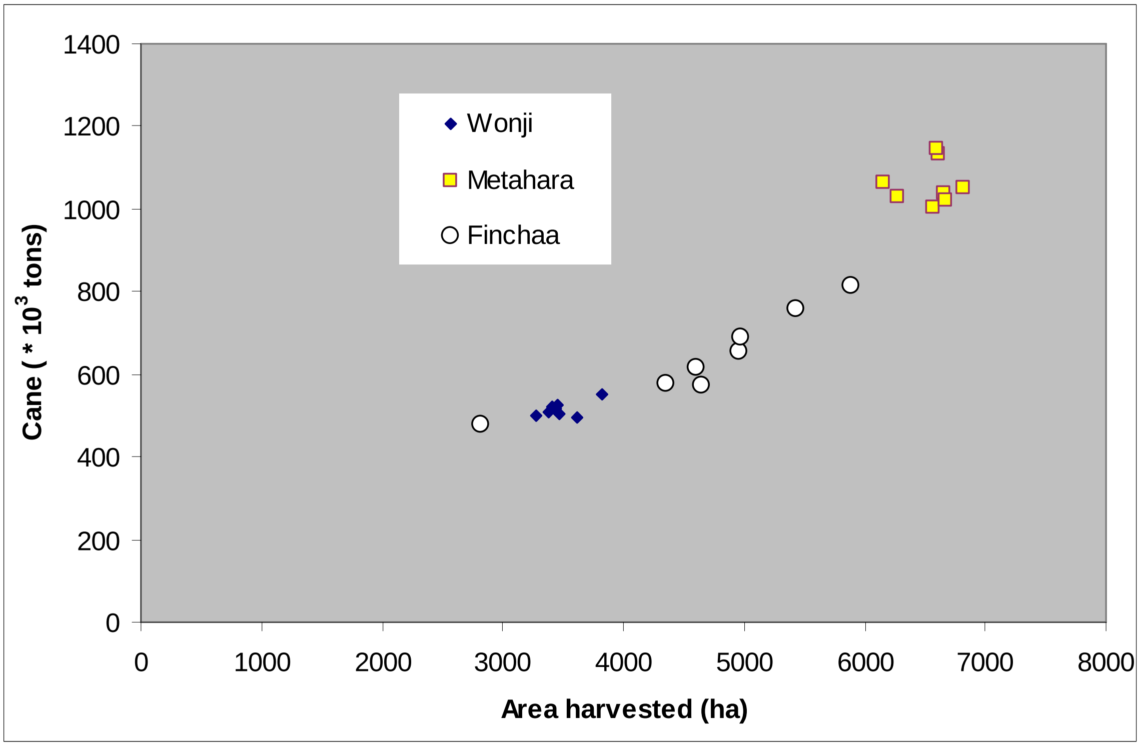

Fig. 3: Comparison of harvested area and cane production (1998/99 – 2005/06)

Annually harvested area and hence total cane production is greater in Metahara sugar estate followed by Finchaa and lowest in Wonji. The regression coefficients (r^2) of the relations given in figure 3 are 0.36, 0.004 and 0.88 for Wonji, Metahara and Finchaa respectively. This shows that both harvested area and cane production was not significantly increased in Metahara and Wonji. In case of these schemes, the points showing the relationships between areas harvested and cane production are concentrated at almost same area. Within the period 1998/99 – 2005/06 the total cropped area has increase from 9911.5 ha to 10145.9ha in Metahara. This is an increment of about 2.4%. However, the size of harvested area was variable from year to year without showing linear increase.

Figure 4 and 5 show the deviation of annual production of sugar cane and cotton from the overall average production of the schemes involved in producing the same crop during the last 9 years. While the productivity of Wonji is consistently close to the average line, the productivity of Metahara scheme is greater than the average and that of Finchaa scheme is lower than the mean productivity of the schemes.

From the two cotton producing schemes, Melka Sedi was found to consistently produce more than average production. On the contrary the productivity of Sille scheme is below average in all 9 years considered except in one year, i.e. 2001/02 (Fig. 5). Although both belongs to the state farms, government managed, the management setup and conditions of physical structures under which they are operating is different. The more than 40 years old irrigation infrastructure in Sille farm and less motivated and unskilled staff as well as low input services are contributed to low productivity of the farms.

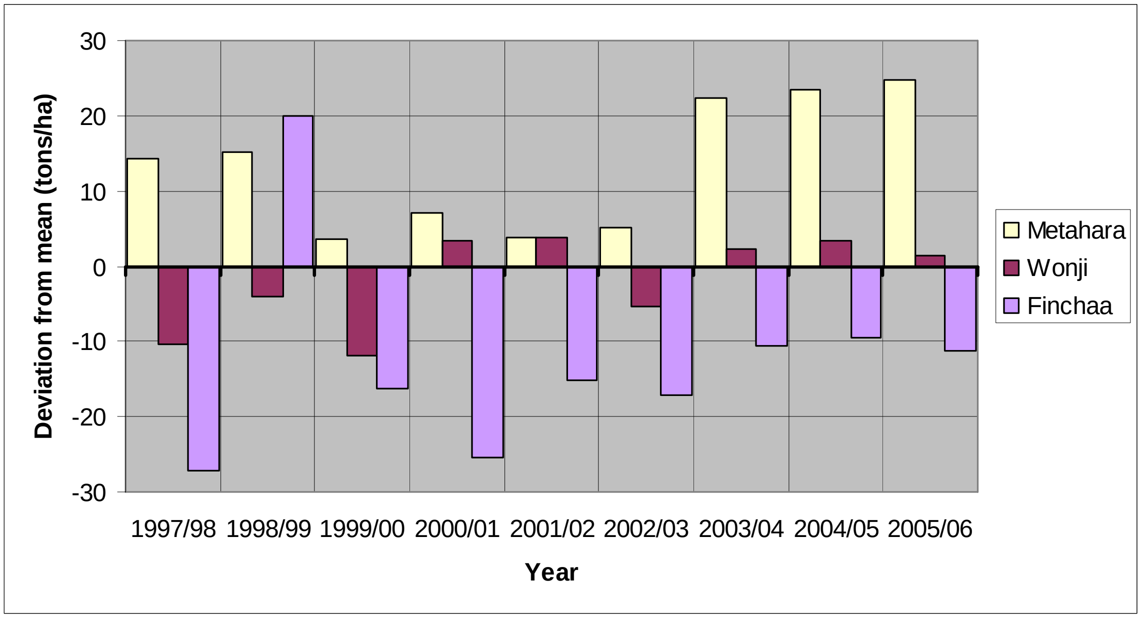

Fig. 4: Deviation of annual sugar cane production from mean, i.e. 149 tons/ha

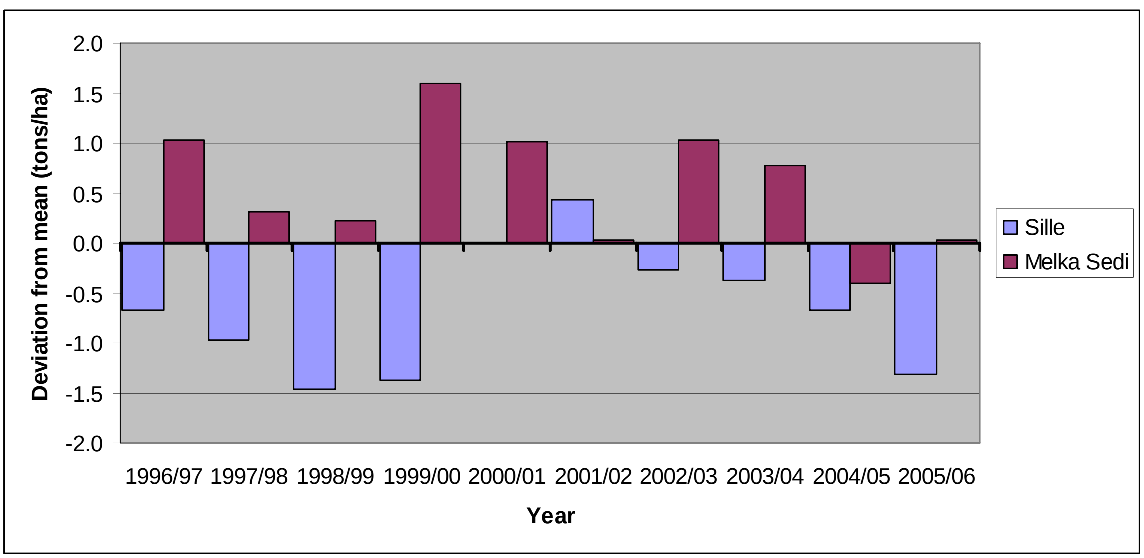

Fig. 5: Deviation of annual cotton production from mean, i.e. 1.97 tons/ha

Although adequate or more water than required is supplied to the scheme, the output obtained in Sille and Hare schemes are very low. It may not be the total amount of water diverted to the scheme which is so important to evaluate the influence of irrigation water on production rather adequacy and uniformity of its distribution on the cropped field.

4.3. Output per units of water supply

Water productivity has been defined as the amount of output produced per unit of water involved in the production, or the value added to water in a given circumstance (Molden et al. 1998). It was calculated by dividing the value of agricultural production obtained from a unit area of land by volume of irrigation water supplied during the production season. Fig. 6 shows the productivity of water for different irrigation schemes.

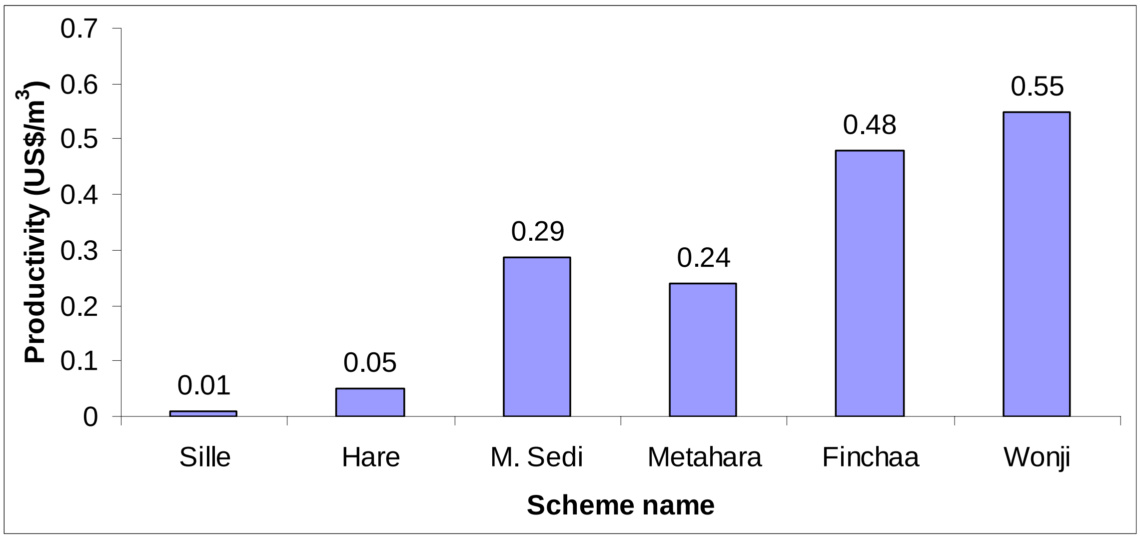

Fig. 6: Output per unit water supplied

Output (US$) per units of water supply (m^3) varies between 0.01 in Sille, 0.05 in community managed scheme and 0.55 US$ in government managed irrigated sugar cane farm. Water productivity in other areas was found to be 0.04 – 0.56 US$ (Merdun, 2004), 0.03 – 0.91 US$ (Molden et al. 1998). Differences have also observed not only between different schemes, cropping and management types but also between the same cropping and management type in different schemes. The results indicate that Wonji irrigation scheme was found to be efficient in economical use of irrigation water followed by Finchaa and Metahara. In terms of cane productivity Metahara was found to produce more. However, sugar gained is more in case of Wonji. This may be due to the differences in the cutting ages adopted by the schemes. Results given in Fig. 6 are also influenced by the value of crops grown, irrigation management and weather conditions such as contribution of rainfall. Proper irrigation scheduling that takes into account the contribution of rainfall during growing season will have improving effect on water productivity. The difference in the water productivity between sugar cane producing scheme is attributed to the management practices. Despite adequate water deliveries at the scheme level (Table 3) in Sille and Hare irrigation schemes, both land and water productivity is low compared to Melka Sedi scheme, producing the same crop, i.e. cotton. It is not the total amount of water diverted to the scheme which so important to influence the production, rather its adequacy, uniformity and proper spreading over the cropped field.

5. Summary and Conclusion

The assessment of irrigation performance in seven irrigation schemes using output and water supply performance showed that there is a tremendous difference between the schemes in their output performance. This is true even for the same cropping and management types. Government agency managed schemes that grow sugar cane have got higher productivity that ranges 123.5 - 173.8 tons/ha, 7794 – 10834 US$ per harvested area and 0.24 – 0.55 US$/$m^3$. On the other hand schemes that grow cotton have relatively low productivity that ranges from 310 US$/ha in community managed scheme to 385 US$/ha in state farm. The water productivity of these schemes is respectively 0.05 and 0.01 US$/$m^3$. It is evident that as the management setup, staffing, capacity, and availabilities of resources are different, not all schemes under similar management and cropping types have similar performance. Then, there is a huge difference in the attainment of the primary objective of irrigation, i.e., increased outputs.
The scheme level values of water supply performance indicators (ARWS and ARIS) revealed that there were no water supply constraints during the season. That means the water supplied during the season (2005/06) could meet the forecasted crop and irrigation water demand in all schemes considered. However, it should be noted that the scheme level values does not give any clue how efficiently, adequately, uniformly, timely and reliably the water was distributed within the farms. It is evident that measuring these indicators requires intensive field data which need to be generated from field level measurements.

Government agency managed schemes that grow sugar cane have got higher productivity that ranges from 123.5 - 173.8 tons per hectare of harvested area, 7794 – 10834 US$ per harvested area (2005/06) and 0.24 – 0.55 US$/$m^3$ of water supplied (2005/06). On the other hand schemes that grow cotton have relatively low productivity and high variations that ranges from 310 – 2077 US$/ha in community managed and state farm. Output per units of water supplied varied from 0.01 – 0.29 US$/$m^3$ of water supplied to the scheme.
Cotton growing schemes are characterized by high productivity variations between seasons. This could be due to inconsistencies in the management systems, input services and inability to minimize the influences of climate conditions through adoption of effective irrigation scheduling. Huge variations between outputs of same crop type in different schemes reveal that there is a room for improvement in the productivity of land and water. However, answer to the question, ‘which one is doing what better and why?’ need the examination of internal process indicators.

Low productivity of irrigated agriculture in schemes such as Hare and Sille is possibly attributed to poor conditions of the irrigation infrastructure, inadequate management capacity and skills, lack of proper operation and on-farm water management practices and procedures, lack of incentives and hence low motivation to improve performance. Investment on improvements of physical structures, management and operation of the system at all levels will bring substantial improvement of performances of these schemes.

Scheme level values of water delivery and supply performance indicators presented in this paper are based on data sets of one year. It doesn’t show also how adequately, uniformly, efficiently and timely the water distributed over the field and field units throughout the season. Hence the scheme level performance indicators are of use for strategic thinking and don’t serve as such operational purpose, because they don’t indicate exactly where the problems responsible for low performance of the system lie. The next study should focus on assessment of performance based on internal processes indicators such as adequacy, uniformity, reliability, efficiency and sustainability.

References

Aklilu Adagn. 2006. Assessment of irrigation system at Sille state farm. MSc-thesis. Arba Minch University, Ethiopia

Belete Bantero. 2006. Across-system comparative assessment of medium-scale irrigation system performance. MSc-thesis. Arba Minch University, Ethiopia.

Bos, M.G., M.A. Burton and D.J. Molden (2005): Irrigation and Drainage Performance Assessment. Practical Guidelines. CABI Publishing, CAB International, Wallingford, UK

Clemmens, A.J., D.J. Molden. 2007. Water uses and productivity of irrigation system. Irrigation systems. 25, 247-261

Gorantiwar, S.D., and I.K. Smout. 2005. Performance assessment of irrigationwater management of heterogeneous irrigation schemes: 1. A framework for evaluation. Irrigation and Drainage Systems. 19: 1-36.

Habib D. 2005. Study on hydraulic performance of some irrigation canals at Wonji sugar state. Proceedings of 9th sysmposium on sustainable water resources development. Arba Minch University. 52-57.

Kloezen, W.H. and C. Garce's-Restrepo. 1998. Assessing irrigation performance with comparative indicators: The case of the Alto Rio Lerma irrigation District, Mexico. IWMI Research Report No 22. Colombo Sri Lanka.

Mohtadullah K. (1993): performance of irrigation systems. 15th- congress on irrigation and drainage. ICID . CIID, 74 – 83.

Molden, D., R. Sakthivadivel, C.J. Perry, C. de Fraiture and WimH. Kloezen (1998): Indicators for comparing performance of irrigated agricultural systems. IWMI Research Report No 20, Colombo, Sri Lanka

Small, L., M. Svenddsen. 1990: A framework for assessing irrigation. Irrigation and Drainage system. 4, 283-312.

Tessema B. 2006. Assessment of hydraulic performances and irrigation potential of Bilate tobacco development irrigation scheme. MSc. Thesis. Arba Minch University, Ethiopia.

Vandersypen, K., Bengaly, K., Keita, A., Sidibe, S., Raes D., Jamin, J.-Y. 2006. Irrigation performance at tertiary level in the rice schemes of the Office du Niger (Mali): Adequate water delivery through over-supply. Agricultural water management, 83, 144-152.

Yercan, M., M. Dorsan, M.A. Ul. 2004. Comparative analysis of performance criteria in irrigation schemes: a case study of Gediz river basin in Turkey. Agricultural Water management. 66, 259 – 266.