Analysis of irrigation systems using comparative performance indicators:

A case study of two large scale irrigation systems in the upper Awash basin

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Abstract

This research was conducted to introduce the concept of evaluating the countries large scale irrigation systems and using the IWMI's minimum set of indicators for the same purpose. This was done by selecting two irrigation systems in the Upper Awash Basin. NuraEra state and Wonji estate farm were selected for their relatively better organization and management, nearness to weather station and their representative nature of the large scale irrigation systems in the country.

The necessary primary and secondary data to calculate the nine indicators were collected which are measurement of canal capacity and pump capacity, and total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production per season or per year, incomes generated from water fee and cropping pattern.

The indicators used are output per cropped area, output per command area, output per irrigation diverted, output per water consumed, relative water supply, relative irrigation supply, water delivery capacity, financial self sufficiency and gross return on investment.

The result of the analysis shows that the ratio of RWS, RIS and WDC for NuraEra are 4.8, 6.6 and 1.4, for Wonji estate 1.36, 1.4 and 0.77 respectively. The four agricultural indicators; output per cropped area, output per command, output per irrigation supply and output per water consumed are in the order of 21017.44, 23791.21, 0.74 and 2.3 for NuraEra and 20074.97, 13916.03, 1.4 and 1.2 for Wonji, respectively. .

NuraEra spent 0.36 percent of its income in the year of analysis and that of Wonji is 0.17 percent for operation and maintenance of the delivery system. FSS was 100% for both of the farms. And gross return on investment was 84.7% for NuraEra and 76.8% for Wonji.

Background

Rapid increases in the world's population have made the efficient use of irrigation water vitally important, particularly in poorer countries, where the greatest potential for increasing food production and rural incomes is often to be found in irrigated areas. It has therefore become a matter of serious concern in recent years that, despite their very high costs, the performance of many irrigation schemes has fallen far short of expectations (FAO, 1986).

The country's irrigation efficiencies are generally low, of the order of 25 to 50%, and problems with rising water tables and soil salinisation are now emerging. As is usually the case, these problems only emerge some 10 to 15 years after project inception. More detailed information on the long-term operational behavior of the existing schemes often results in optimum design at the planning stage of the new schemes, leading to lower capital and lower overall costs, the avoidance of costly remedial works in the long term and achieving maximum returns on water (Woodroofe, 1993).

State run farms, which include large-scale irrigation systems, were reiterated as major components of efforts to develop the country's agricultural sector, notably in the Awash Valley. However, productivity of these top–down managed systems over the decades has been disappointing—the farms have been beset by a number of environmental**,** technical and socio-economic constraints. The large scale systems in the Awash basin and elsewhere suffer from water management practices that have resulted in rising ground water tables and secondary soil salinisation where large tracts of land have gone out of production (EARO 2001; Paulos).

Even if evaluating the existing irrigation systems is an old phenomenon in the other parts of the world; it has not been tried in Ethiopian large-scale farms. Hence, this study attempts to introduce the concept of comparative performance indicators as a tool to evaluate the performance of large-scale irrigations in the Upper Awash valley.

The indicators

Nine indicators are developed related to the irrigation and irrigated agricultural system. The main output considered is crop production, while the major inputs are water, land, and finances.

Indicators of Irrigated Agricultural Output

The four basic comparative performance indicators relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

Output per unit of irrigation water supplied and output per unit of water consumed are derived from a general water accounting framework (Molden et al, 1998). The water consumed in equation 4 on page 21 is the volume of process consumption, in this case evapotranspiration. It is important to distinguish this from another important water accounting indicator—output per unit total consumption, where total consumption includes water depletion from the hydrologic cycle through process consumption (ET), other evaporative losses (from fallow land, free water surfaces, weeds, trees), flows to sinks (saline groundwater and seas), and through pollution.

We are interested in the measurement of production from irrigated agriculture that can be used to compare across systems. If only one crop is considered, production could be compared in terms of mass. The difficulty arises when comparing different crops, say wheat and tomato, as 1 kg of tomato is not readily comparable to 1 kg of wheat. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as net value of production and gross value of production using local values.

$$\textit{Output per cropped area} = \frac{\text{Production}}{\textit{Irrigated Cropped area}} \quad (1)$$

$$\textit{Output per unit command area} = \frac{\text{Production}}{\textit{Command area}} \quad (2)$$

$$\textit{Output per irrigation supply} = \frac{\text{Production}}{\textit{Diverted irrigtion supply}} \quad (3)$$

$$\textit{Output per unit water consumed} = \frac{\text{Production}}{\textit{Volume of water consumed by ET}} \quad (4)$$

Where,

Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices,

Irrigated cropped area is the sum of the areas under crops during the time period of analysis,

Command area is the nominal or design area to be irrigated,

Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater, and

Volume of water consumed by ET is the actual evapotranspiration of crops.

Five additional indicators were identified in this minimum set for comparative purposes. These are meant to characterize the individual system with respect to water supply and finances.

Relative water supply and relative irrigation supply are used as the basic water supply indicators:

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop demand}} \quad (5)$$

(6)

Where:

Total water supply

= Surface diversions plus net ground water draft plus rainfall.

Crop demand

= Potential crop ET, or the ET under well-watered conditions.

Irrigation supply

= only the surface diversions and net groundwater draft for irrigation.

Irrigation demand

= the crop ET less effective rainfall.

Relative irrigation supply is the inverse of the irrigation efficiency Molden et al (1998). The term *relative irrigation supply* was presented to be consistent with the term relative water supply, and to avoid any confusing value judgments inherent in the word *efficiency*.

Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Care must be taken in the interpretation of results: an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

$$\text{Water delivery capacity}(\%) = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}} \quad (7)$$

Where:

Capacity to deliver water at the system head

= the present discharge capacity of the canal at the system head, and

Peak consumptive demand
= the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

Water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. Again, a lower or higher value may not be better, but needs to be interpreted in the context of the irrigation system, and in conjunction with the other indicators.

Financial Indicators

The two financial indicators are:

$$Gross\ return\ on\ Investment\ (\%) = \frac{production}{Cost\ of\ irrigation\ structure} \quad (8)$$

$$Financial\ self\ sufficiency = \frac{Revenue\ from\ irrigation\ service\ fee}{Total\ O\ \&\ M\ expenditure} \quad (9)$$

Where,

Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the SGVP,

Revenue from irrigation, is the revenue generated, either from fees, or other locally generated income, and

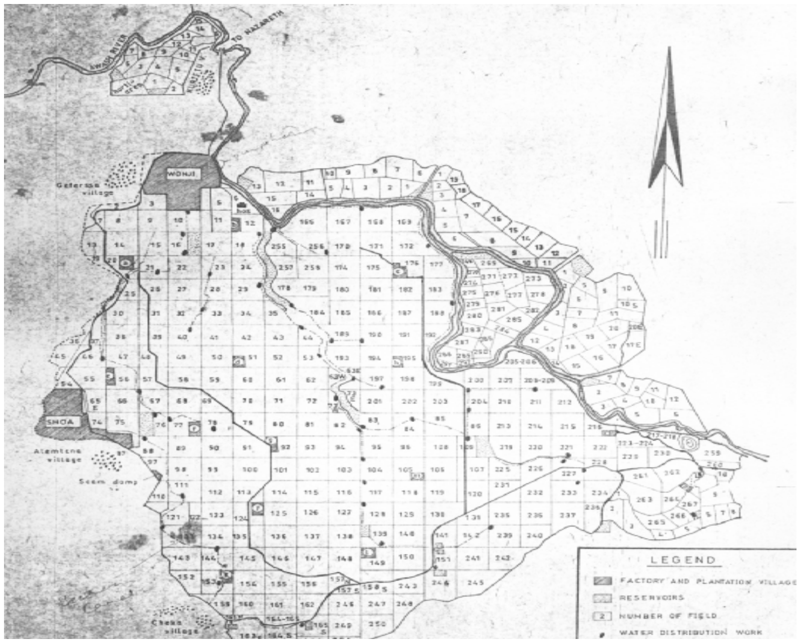
Total O & M expenditure is the amount expended locally through operation and management

Description of the Study Area

The mean annual rainfall of Awash Basin varies from about 1600mm at Ankober; in the highlands north east of Addis Ababa top 160mm at Asayta on the northern limit of basin. Addis Ababa receives 90% of its annual rainfall during the rainy period March to September. At Dubti the same over all proportion is received during the two rainy periods, distributed 30% and 60% respectively. The mean annual rainfall over the entire western catchment is 850mm and over the head waters of Awash, as gauged at Melka Hombole it is 1216mm.The annual and monthly rainfall are characterized by high variability (Halcrow, 1989).

Wenji Estate farm

The estate was constructed by HVA in the early 1960s .It comprises 5925ha of sugar and is operated by the ESC (Halcrow, 1989). The estate is located in the central east part of the main Ethiopia rift system, 107 km southeast of Addis Ababa. It is found between $8^0$30' to $8^0$35'N and $39^0$20'E grid and at an altitude of 1540 m a.s.l Average Maximum and Minimum temperature are 27.6^{0}C and 15.30C, respectively. The surrounding topography is steep on all sides north and east being bound by river awash the west and the south by the border drain which protects the estate from the run off and sedimentation from those steep slopes (Mukherji, 2000). Irrigation supplies are provided by continuous electrical pumping from the Awash into a settling basin at the head of the main canal. Night storage reservoirs cover a surface area of 60ha (Halcrow, 1989).



Nuraera state farm

The farm is found in the eastern showa administration zone. It is divided in three sub farms. From the total land owned by the farm which is 3,277ha, 3,069 ha is covered by crops the remaining 208 ha by infrastructures. The farm has been developed on an adhoc basis over several years and water abstraction is by gravity.

Canals and irrigation layouts have not been formally designed so that their capacities are not listed.
Water use efficiencies would appear to be in the range of 20%-30% (Halcrow, 1989). Irrigation of citrus is generally by small basin around tree bases.

Main gate on the main canal at Nuraera

Diversion Weir at Nuraera

Abstraction is measured by staff gauges in the main canal from gravity offtakes irrigation is generally undertaken 24 hours a day. Wastage of water is inevitable but it appears that little, if any flow is returned to Awash. The northern end of the canal used to outfall into Lake Beseka. This has been stopped by a cut-off-drain which is partly constructed with the objective of leading the flows back to Awash.

Methodology

After reconnaissance survey and consulting the officials of the Upper Awash agro-industry enterprise, one farm was selected among the three farms of the enterprise. NuraEra farm was selected for its nearness to the weather station, relatively better organization and management and availability of secondary data. Moreover the other two farms are medium scale farms.

The other farm selected for its attributes of nearness to Addis Ababa and wheather station and the availability of data were Wonji sugare estate.

Secondary data collections were started in February 2005 in collaboration with the farm officials.

Primary data collection

The job of primary data collection which is measurement of canal capacity and pump capacity was started in April 2005 in collaboration with the department of hydrology in the Ministry of Water Resources.

The upper Awash Water Administration center installed a BOC on the main canal at around 200m from the diversion weir for the purpose of updating its rating curve for the reason that the flow characteristics changes due to high rate of sedimentation resulting in change of canal morphology.

The plotted rating curve was used to find out the total water diverted using the daily records of the gauge height taken by main gate operator who is an employee of the center.

But due to the shortage of material and manpower, the center has been using
the old rating curve for the purpose of knowing the total amount of water diverted. Due to the high siltation rate and the changing nature of the hydraulic condition in the main canal , it will be hard to get a reliable data using a rating curve plotted two years ago. For this reason it was decided to measure the discharge at various gage heights and take the average discharge to calculate the amount diverted for each season.

Maintaining the abandoned BOC took much of our time before engaging in the measurement.

Preparation for work at Nuraera

In the case of Wonji showa estate farm, the pumps in the main pump station are more than 40 years old. Their Design capacity went on reducing through these years. Therefore the current capacity of each pump should be measured. That can be done either by measuring the water depth over the cippoleti weir and use the formula to calculate the discharge or by measuring the flow on site.

The measurement was taken at 0.2*the depth of water over the weir crest measured from the surface of the water and the width of the crest was divided by 0.2m interval(see appendix B).

Measuring discharge from cippoleti weir at Wonji

Secondary data collection

The Secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production per season or per year, incomes generated from water fee and cropping pattern.

Climatic data of Wonji farm were collected from the nearby station at wonji while that of NuraEra were collected from the head office of Ethiopian National Meteorological Agency in Addis Ababa.

Since both farms have a planning and program department run by skilled manpower, they kept good number of years record of the production and prices
of crops. For instance, wonji have a 50 year data of production.

The only problem in the case of the needed secondary data was the record of money spent for operation and maintenance of the irrigation systems

Results and Discussion

Nuraera
After measuring the discharge at various working gauge heights, the average discharge was estimated to be 3.1 m^3/s. And this discharge was used to estimate the amount of water diverted in the year 2003/04.
Based on the collected data of planting and harvest of each crop for the year of analysis, the agricultural practice of the farm is divided into two seasons. The first season of cropping goes from January to July, the amount diverted in these months was.
Season A $3.1*212*24*60*60 = 56,782,080\ m^3$
Season B $3.1*153*24*60*60 = 40,979,520\ m^3$

Total amount of water diverted for the year 2003/04 = $97,761,600m^3$

Total output of NuraEra farm for the year 2003/04

Crop	Area (ha)	Production in Qt.	Unit price in birr/Qt.	Total Output in Birr
Orange	772	254,580.6	112	28,497,753.48
Manderine	181	35,844	87.50	3,133,836.55
Guava	55	1,307.2	32.20	42,038.27
grape Vine	11.18	538.3	400	215,304.00
Mango	40.35	9,395	117.75	1,106,250.65
Tomato	224.53	35,115	40.60	1,424,968.73
Onion	54.12	4,790	136.50	653,925.34
Green chilies	5.30	182.	134.60	24,494.91
Cabbage	0.55	23.6	40.60	959.31
Carrot	0.30	22.2	40	889.64
Beet root	0.45	36	40.00	1,444.40
Beans(local)	2.00	1,463.8	61	89,323.52

Bobbybeans(export)	149.50	6,221.8	1,383	8,604,265.49
Okra	0.60	3	172	532.92
Maize	350.00	17,002.6	120.20	2,043,368.86
Pop corn	58.60	385.7	483.30	186,411.74
Cotton	735.00	18,061.8	1,494.30	26,989,446.28
Total	2,640.5	384,973		73,015,214

As it is clearly seen the farm used wider cropping pattern. And based on the planting and harvesting dates of each crop, the whole year is divided into two seasons and their CWR and irrigation requirement was calculated using CROPWAT 4.2. The result is as shown below:

CWR and IR of each crop

	SEASON A			**SEASON B**		
Crop	Area(ha)	Crop water requirement (mm/season)	Net irrigation requirement (mm/season)	Area(ha)	Crop water requirement (mm/season)	Net irrigation requirement (mm/season)
Tomato	220.5	760.68	613.44	224.53	712.92	446.05
Onion	47	490.79	389.56	54.12	489.76	243.78
Vegetables	8.15	515.89	413.39	7	493.45	242.48
Beans	150	427	330.55	151	424.51	178.94
Maize	408.6	684.37	495.58	408.6	537.53	416.32
Cotton	735	999.13	634.58			
Citrus*	1008	1334.31	873.46			
Mango*	40.35	1973.22	1512.36			
Grape wine*	11.18	1057.43	596.58			
Total	2628.78			845.25		

* Perennial crops

To calculate the first four indicators grose production was taken instead of SGVP because of the fact that there is no price difference in the two irrigation systems and no common crop is grown in both the farms. Sugarcane is not grown in NuraEra farm but it is the only crop in Wonji sugar estate.

1. $Output\ per\ cropped area$

$$= \frac{production}{Irrigated cropped area}$$

= 73,015,214.08 / (2628.78+ 845.25)
= 73,015,214.08 / 3474.03
= 21,017.44 birr/ha

2. $Output\ per\ unit\ command\ area$

$$= \frac{production}{Command\ cropped\ area}$$

Out put per unit command area
= 73,015,214.08 / 3,069
= 23,791.21 birr/ha

3. $Output\ per\ irrigation\ \sup ply$

$$= \frac{production}{Diverted\ irrigation\ \sup ply}$$

= 73,015,214.08 /97,761,600
= 0.75 birr/m^3

Then, the net crop water requirement and the net irrigation requirement (IR) are computed for each irrigated crop and for each growing season (option 2 in CROPWAT main menu). The crop coefficients provided with CROPWAT program are used (input: planting dates and growth length in days). The outcomes were:

The total net crop demand for season A is (refer table 4.2):

CWR_{tomato}* (area $_{tomato}$ / area $_{total}$) + CWR_{onion}* (area $_{onion}$/ area $_{total}$) + etc. =

760.68* (220.5/2628.78) + 490.79* (47/2628.78) + 515.89* (8.15/2628.78) + etc.

= 1,030.70 mm/season

In the same way, the total net irrigation requirements are computed. The efficiency used is 40%. This percent was set basing the estimation of Halcrow(1989) and allowing for the improvements of the years between the year of study and the year of analysis.

SEASON	NCWR*	NIR**
A(Jan-July)	1,030.70	693.7
B(Aug.-Jan)	560.5	369.3
Total	1591.2	1063

*Net crop water requirement
**Net irrigation requirement

$$Output\ \ per\ unit\ water\ consumed = \frac{\text{Pr}\, oduction}{Volume\ of\ water\ consumed\ by\ ET}$$

Where *Volume of water consumed by ET* is the actual evapotranspiration of crops.

$= 73,015,214.08 / (1,030.70*2628.78+ 560.5*845.25)*10^{-3}*10^{4}$

= 2.3 birr/m3

5. *Relative water supply*
= (Irrigation derived + total precipitation) / CWR

Diverted irrigation in mm
Season A = 56,782,080 / 2628.78*10 = 2160 mm
Season B = 41,247,360 /845.25*10 = 4879.9
Total = 7039.9
RWS = (7039.9+566.9)/1591.2
= 4.8

6. *Relative* irrigation *supply*
= Irrigation applied / irrigation requirements
= 7039.92/1063
= 6.6

The scheme irrigation requirement was calculated with CROPWAT (option 4 in main menu) using the climate data, cropping pattern, planting dates, and area.
For 2003/04, the scheme irrigation requirements were:

Scheme irrigation requirement of NuraEra farm

	Jan.	Feb.	March	April	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
IR in l/s/ha	0.37	0.39	0.69	1.13	1.2	0.77	0.75	0.73	1.47	1.4	1.17	0.59

Peak irrigation requirements occur in September, 1.47 l/s/ha.
Peak demand is 1.47 * cropped area for that month =1.47 *2639.78= 3880.48 l/s.
As explained above the canal capacity was measured using bank operated cable. The result was 5.4 m^3/s

7. *Water delivery capacity*: 5,400 lit. / 3,880.48 lit. = 1.4 or 140%

8. *Gross return on investment =Production / cost of irrigation infrastructure*

The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development. Since it was not possible to get the design documents of the two projects, the document of other projects with more or less similar structural condition were taken. After studying the documents of the similar irrigation projects in Awash Basin, the Angelele and Bolhamo design document were used for their better similarity and nearness to NuraEra and Wonji to estimate the cost of distribution system per hectare.

All the delivery system of the NuraEra farm is earth canals .Therefore the cost of earth canals per hectare in these documents is found to be 1497.9 4 birr
The formula to calculate the present worth is.

$$Present\ Net\ Worth(PNW) = (Initial\ \cos t / ha) \times (1 + r)^n$$

Where: *r* is interest rate, which is taken from the design document of Angelele Irrigation Project and *n* is years from construction time.

PNW = $1497.94(1+0.1)^{30}$
= 26138.2birr/ha

The cost of delivery system of NuraEra
= 26138.2 birr/ha *3069 ha
= 80,218,006 birr

Therefore Gross return on investment
= 73,015,214.08 birr/ 80,218,006birr
= 91%

9. Financial self-sufficiency
= Revenue from irrigation/Total O&M expenditure

Where, *Revenue from irrigation,* is the revenue generated, either from fees, or other locally generated income, and Total *O&M expenditures* are the amount expended locally through O&M plus outside subsidies from the government.

Even if the Upper Awash Water Administration Center collects water fee at the rate of 3 birr per 1000 m^3 of water, no money was spent for maintenance and operation in the year of analysis. Rather the farms perform some clearing and maintenance work whenever they feel necessary. Thus the income generated from the farms doesn't go to the purpose of operation and maintenance.

However the intent of IWMI indicator number 9 is to see how much of the cost of operation and maintenance work is generated locally. In this context we can say that both farms are 100 % self sufficient. It was learnt from the farm record that the amount of money spent for operation and maintenance of the delivery systems for the year 2003/'04 was 260,317.23 birr.
= 260,317.23/260,317.23
= 100%

In this respect, the management of these two farms is a little bit different to that of normally practiced. In order to have additional information for evaluating that part which is related to maintenance and operation, one more indicator is developed and added in this paper. This indicator atleast will give us additional insight on the relative focus given to the delivery systems.

$$Percent\ \ allocated\ \ to\ \ O\ \&\ M = \frac{Total\ \ O\ \&\ M\ \exp enditure}{\Pr oduction}$$

= 260,317.23/ 73,015,214.08
= 0.36 %

Wonji Sugar estate

The only crop grown in this farm is sugarcane. The kind of irrigation practiced at Wonji may be termed ''blocked end furrow irrigation system''. Water applied each furrow is cut off as it reaches the end of the furrow ,which is blocked ,and ponds up within the furrow .The furrow length for the part of the field (anjir) depends on the gradient available and three lengths 32m,48m,and 64m are being used currently. The advantages of this system are that there is no run off and the entire water applied to the field incorporated into the soil. As such, in addition to the infiltration characteristics of the soil, the size of the inflow stream and the gradient of the furrow become important variables to control the rate of advance of water front to the end of the furrow, which determines the cutoff time for the inflow. (Mukherij, 2000)

Production and area of Wonji estate for the year 2003/04

Command area(ha)	Irrigated area(ha)	Production(qtl.)	Farm gate price(birr/qtl.)	Income (birr)
5,929	4,110	7,446,581	11.08	82,508,117.5

The main pump station at Wonji has a total of eight pumps with a design discharge of (6*750+2*500)5500 lps .According to Mukherji the two vertical shaft pumps are working with overall efficiency of 68% and the other six horizontal shaft pumps with an efficiency of 50% of their designed capacity.

Crop water requirement mm/year	Irrigation requirement mm/year
1,667.1	1,054.33

The result of our measurement almost agrees with that of Mukherji, The current capacity of the two vertical shaft pumps is 240.3 lps and the horizontal shaft pumps are with a capacity of 488 lps. Therefore the maximum discharge that can be pumped for irrigation purpose is 3,165.34 lps allowing 10% for factory use.

1. Out put per cropped area
   = Out put / irrigated cropped area
   = 82,508,117.48 / 4,110
   = 20,074.97 birr/ha

2. Out put per command area
   = Out put / command area
   = 82,508,117.48/5929
   = 13,916.03 birr/ha

3. Out put per irrigation supply
   = Out put / irrigation diverted
   = 82,508,117.48/75320000
   = 1.1 birr/m^3

4. Out put per unit water consumed
   =out put/Volume water consumed by ET

Volume of water consumed by ET
= 1667.1*4110*10 m^3
= 68,517,810 m^3

Out put per unit of water consumed
= 82,508,117.48/68,517,810
= 1.2 birr/m^3

5. Relative water supply
= (Irrigation derived + total precipitation) / CWR
= (1,466.08 + 817.3)/1667.1

= 1.36

= 1,466.08/1,054.33
= 1.4

6. *Relative irrigation supply*
= Irrigation applied/ irrigation requirements

For 2003/04, the scheme irrigation requirements were:

IR in	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
l/s/ha	0.4	0.58	0.94	0.93	0.87	0.65	0.31	0.23	0.73	1	0.94	0.85

Peak irrigation requirements occur in October, 1 l/s/ha.
Peak demand is 1 * cropped area for that month = 1 * 4110 = 4110 l/s.

7. Water delivery capacity: 3,165.34/4110
= 0.77 or 77%

8. The same procedure was applied to Wonji to calculate gross return on investment except that irrigation structure costs are included since all the necessary structures are found in Wonji estate farm. The present initial cost per hectare of the delivery system is found to be 26137.5 birr.

Gross return on investment
= 82,508,117.5 birr / 235,727,927.5 birr
= 35%

9. Percent allocated to O&M
= 139,330.46/ 82,508,117.48
= 0.17%

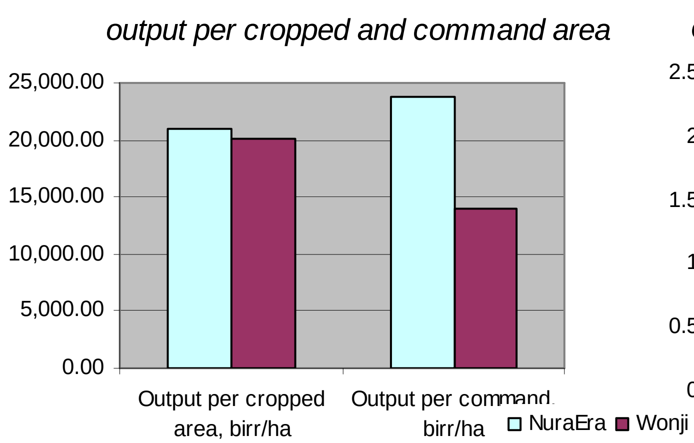
Comparative analysis of the two irrigation systems

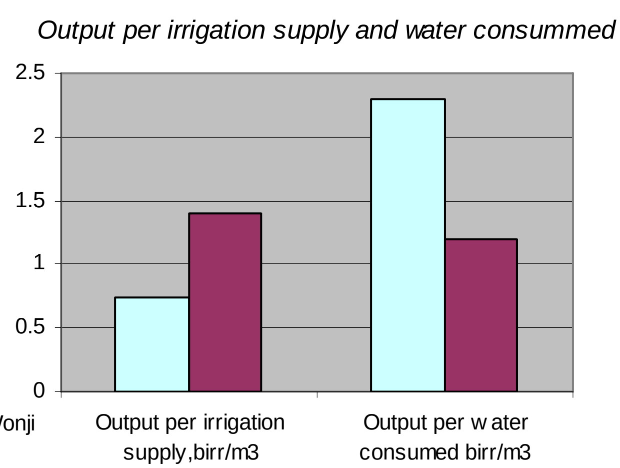
The four basic comparative performance indicators relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agriculture performance (Molden, 1998).

The values of the four indicators for the respective farms are as tabulated below.

summary of the four indicators

Site	Output per cropped area, birr /ha	Output per command, birr/ha	Output per irrigation supply,birr/m^3	Output per water consumed birr/m^3
NuraEra	21,017.44	23,791.21	0.75	2.3
Wonji	20,074.97	13,916.03	1.4	1.2



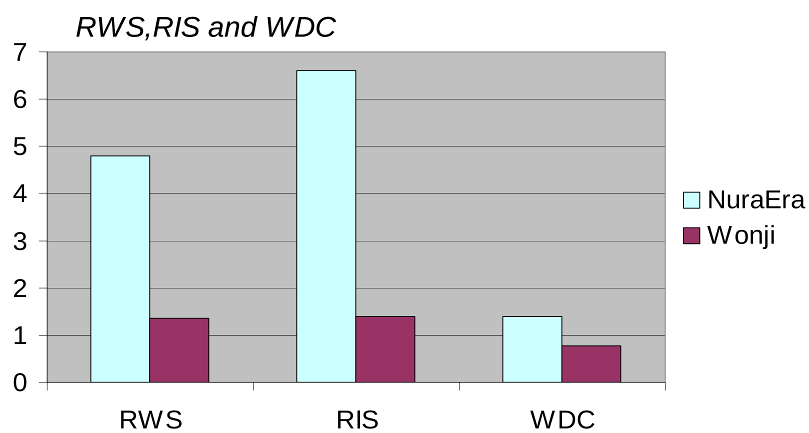


As clearly seen in the first table and chart, NuraEra is higher in output per cropped area and output per command. This is attributed to the high value and export crops grown in the farm and also the higher cropping intensity.

In the case of output per irrigation supply Wonji has the higher value (1.4) implying that Wonji is better in effective utilization of water. But as the indicators are comparative we can't say that Wonji achieved the required performance. NuraEra show a generous supply of water. Using the rainfall in a better way than that of the NuraEra contributes for this higher value of output per irrigation in Wonji. In other words NuraEra is better in land productivity and Wonji show better performance in water productivity.

Result of RWS and RIS

Site	Relative water supply	Relative irrigation supply	Water delivery capacity
NuraEra	4.8	6.6	1.4
Wonji	1.36	1.4	0.77



Higher values of RWS and RIS indicate a more generous supply of water (Molden, 1998). In our case, NuraEra show this fact which means productivity to land is more important. In the Wonji farm we have more constrained supply of water so that productivity per unit of water is more important. These two values can be minimized by adjusting the release of water from storage or diversion with the available rainfall.

The lower values of RWS and RIS of Wonji estate farm is not mainly the result of good management rather the decreasing capacity of the pumps limiting the supply. As the result of the measurement conducted showed, 35 and 52 percent decrease in the capacity of the horizontal and vertical pumps has been witnessed respectively. With this capacity, the pumps are not enough to satisfy peak irrigation demand. This will get worse unless a major rehabilitation work of the pump house is done.

On the other hand high value of RWS and RIS is of for NuraEra. This result was expected by the researcher at the end of reconnaissance survey of the area because of two main reasons: one the 34 km main canal is not well maintained and the absence of the necessary irrigation structures in the line of the canal expose the system for very low efficiency, second the farmers around the state farm steal water from the main canal. Consequently much water is lost through its way to the field.

Unauthorized diversion from the main canal at NuraEra

A high value of financial self-sufficiency does not automatically indicate a sustainable system as the O&M expenditures might be too low to meet the actual maintenance needs (Molden, 1998).Thus the high value of FSS of the two farms doesn't show that the expenditure satisfies the operation and maintenance needs. Rather as Molden et al. (1989) explained financial self-sufficiency tells us what percent of expenditures on O&M is generated locally. If government subsidizes O&M heavily, financial self-sufficient would be low, whereas if local farmers through their fees pay for most of the O&M expenditures, financial self-sufficiency would be high.

NuraEra and Wonji are 100% self sufficient meaning all the expenditures for operation and maintenance generated locally from the income of these two farms. Interms of percent allocated to operation and maintenance NurEra is better. This is because of high silt deposit rate in the delivery systems. With out frequent clearing of the system normal operation of the farm can't be carried out.

GRI of the NuraEra and Wonji are 84.7% and 76.8% respectively. NuraEra show a higher rate of return. This is mainly because of the lower investment cost and higher productivity of the farm. But it is hard to say that this system is better than that of Wonji because it is taking much money for its maintenance. Consequently its sustainability is in big question of such systems

Conclusion

The higher values in RWS and RIS combined with the lower ratio of output per water consumed in NuraEra shows that the availability of water is not a problem. In addition it can be inferred that the issue of water management is in jeopardy. The main reasons for this problem are the meager attention given by the farm for irrigation water management, the low water rate and the effect of unregistered users.

As to Wonji farm the low value of WDC can be early warning indicator. This is meant to say that the pump capacity is deteriorating and is not in position to satisfy peak irrigation demand. This problem may manifest itself by reducing production in near future. This has big implication on the production of sugar. WDC of NuraEra farm seems in a better position but the increasing sedimentation and the absence of silt excluders put its sustainability in question.

Both farms spent less than one percent of their income for operation and maintenance of delivery systems. This by itself shows the very low attention given to the irrigation systems. But in relative terms NuraEra was better.

The rate of gross return on investment is high for both of the farms.

Furthermore, as explained in the literature review part, there are varies types of institutional designs of the irrigation systems adopted in different part of the world. This part has not been given the proper attention in our country. As a result, the irrigation delivery systems are left unattended for many years. The case of the two irrigation systems is not an exception. The management of the farms, having their main objective on productivity, didn't give the proper attention for their irrigation delivery systems. This can be seen by the fact that the two farms have no separate irrigation department despite being very profitable ones. Moreover no permanent budget is allocated for irrigation system maintenance.

This research managed to show some of the problems that our large scale irrigation systems are in. The lack of awareness in the farm officials on one side and policy problem in the other left the irrigation systems with lots of problems. Water logging, deterioration of canal capacity and salinity are coming faster.

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