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Evaluation of Irrigation Water Pricing Systems on Water Productivity in Awash River Basin, Ethiopia

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Abstract
Awash basin is the only basin that operates with the concept of river basin management and irrigation water pricing in Ethiopia. The effectiveness and impacts of the current irrigation water pricing system in the basin has not been studied yet. Hence, the objective of this research is to evaluate effects of irrigation water pricing on scheme level water productivity in Awash River basin.
Based on systematic selection criteria, 29 irrigation water users were selected from middle and upper Awash. Structured questionnaire and discussions have been used to generate the primary data. Scheme specific data such as area cultivated, amount of water diverted each year, water fee, service charge and operation and maintenance cost for primary irrigation canals of each legal water user in the basin for five consecutive production years (2005/06-2009/10) were collected from Awash Basin Authority. SPSS and CROPWAT were used to analyze the information gathered through questionnaires and irrigation water requirement respectively. Water productivity of cotton, sugarcane and onion was computed for total available water (excess rainfall + irrigation), irrigation water and water lost through crop evapotranspiration.
The current irrigation water pricing in Awash basin seems to be low and does not encourage individual users in improving water productivity. Hence, it is resulted in low crop water productivity. Therefore, cost of irrigation water in Awash basin should have to be optimized with a well specified and revised pricing objective(s) if it has to influence the water productivity.
Keywords: Irrigation, irrigation water pricing, water productivity, Awash basin

Introduction

Irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a cornerstone of food security and poverty reduction in Ethiopia. Irrigation is one means by which agricultural production can be increased to meet the growing food demands in Ethiopia (Awulachew *et al*., 2005). Robel (2005) also states that one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales, through river diversion, constructing micro dams and water harvesting structures.
However, growing population with higher cultivation intensities, increasing urbanization, computation of sectors for water allocation and environmental concerns have all combined to put pressure on global water resources. Failure of attention to management aspect of irrigation has resulted not only in degradation of productive land but also caused other environmental externalities. This is evidenced by the degradation of irrigated areas like in Awash River basin. In lower Awash, from the total area of 10285 ha of land which was brought under surface irrigation system in the year 1982, about 33% of that area was abandoned due to salinity after only 5-8 years of operation (Girma and Fantaw, 2005). Despite of their promise as engines of food security, irrigation projects typically perform far below their potential. Head-tail problems, leaky canals and malfunctioning structures because of delayed maintenances, leading water use efficiency and low yields are some of the commonly expressed problems. Large part of low performance may be due to inadequate water management system at system and field level (Cakmak *et al*., 2004).
To make irrigation projects sustainable both economically and environmentally, users need to improve their agricultural productivity which requires changes in their institutional structures, water use management systems and policies, improve their service delivery systems, and proper management of farm lands.
Irrigation water pricing is an effective mechanism to generate revenue for sustainable management of irrigation system and at the same time enhance efficient water use and improve water productivity. Irrigation water pricing increases the production rate per unit use of water, reduce the loss of water to unusable sinks and reallocate water for higher priority uses (Howell, 2001). Reddy (2009) also state that irrigation water pricing has an important role in revenue generation for irrigation operating agencies, improve economic efficiency of water resource use, improve equity and fairness among water users, and to enhance water resource conservation. Hence, pricing of irrigation water can be used as an economic, a financial or an environmental tool (Molle and Berkoff, 2007).
Water pricing is seen as a key economic and policy instrument to improve the sustainability of water management, to encourage conservation and improvement of quantitative and /or qualitative status of water

bodies (Johansson *et al*., 2002; Shajari *et al*., 2008; Zoudmides and Zacharides, 2009; Thaler, 2010).
Despite the fact that irrigation water pricing is considered as an important tool to improve efficiency in resources utilization, it is not a common practice in Ethiopia. Although at infant stage and constrained by many problems water pricing is practiced in Awash River basin.
This study was conducted to assess current status of water productivity (crop yield per water consumed) at scheme level for selected crops in Awash River basin and evaluate the effects of water pricing system on irrigation water productivity in the basin.

Methodological approach
A structured questionnaire survey with face to face interview method was used to collect a data about irrigation water pricing systems in Awash basin. In order to conduct the questionnaire survey and discussions representative irrigation water users were selected. The list of all legal irrigation water users, their annually cultivated area, location within the basin, means of water abstraction from the river and their farming system was collected from Awash Basin Authority (ABA). Representative irrigation water users were selected systematically with consideration of users irrigation management institute (private farm, community farm and state farm), crops under cultivation and users location (upper and middle Awash).
Based on the above selection criteria 29 irrigation water users were selected from middle and upper Awash. No irrigation scheme is included from lower Awash, because most large and medium scale irrigation schemes in the area are currently abandoned due to construction of Tendaho and Kessem irrigation projects. 20 small scale (command area less than 200 ha), 5 medium (201-3000 ha) and 4 large scale (more than 3000 ha) irrigation schemes were included in the detail survey of this study.
A structured questionnaire survey was used to collect all necessary primary data about irrigation water pricing from these selected individual irrigation water users in the basin. The questionnaire used for this study was designed in attempt to collect area cultivated by individual user, annual production, individual irrigators yearly water demand, impact of irrigation water pricing on users water demand, individual users response to irrigation water pricing.
Water resources management policy, sector strategy and different regulations and proclamations were reviewed to state the legal frame work of water resource management and irrigation water pricing systems in Ethiopia. Discussions were also held with officials and experts from Ministry of water resources and Energy (MoWRE) and Awash basin authority (ABA) about irrigation water pricing experiences and its impacts in Ethiopia and Awash River basin respectively.
Scheme specific data such as area cultivated, amount of water diverted each year, water fee, service charge in the basin for the last five consecutive production years (2005/06-2009/10) were also collected from ABA. Monthly climate data were also collected from representative meteorological stations (stations near to the selected irrigation schemes) for the analysis of water productivity of selected crops in the basin.

Method of data analysis
The quantitative and qualitative data collected from the primary sources were analyzed using qualitative methods and descriptive statistics. Statistical Package for Social Sciences (SPSS) was used for the analysis of quantitative data to estimate the response of irrigation water users to irrigation water pricing and impacts of irrigation water pricing on water productivity. Data collected from key informant interviews, discussions and observations were qualitatively assessed to state the current irrigation water pricing system, its objectives and its practical application in Awash basin. Finally, outputs of the statistical analysis were presented using tabulation, cross-tabulation, means, frequencies and percentages.

Water productivity
Nowadays, there is a trend to call improving irrigation water productivity as a must (Molden *et al.*, 2003). Molden and Theib (2007) defined water productivity as the ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits. Water productivity may be generically defined as the ratio between the actual yield achieved (Ya) and the water used expressed in Kg/m^3. Water productivity (WP) can be expressed either in physical or economic terms (Kumar *et al*., 2009; Yokwe, 2009). Water productivity broadly denotes the outputs (physical or economic) derived from a unit volume of consumed or depleted water. Water productivity combines accounting of water with crop yield or its economic return to indicate the value of a unit volume of water. Depending on how the terms in the numerator and nominator are expressed, water productivity can be expressed in general physical or economic terms. In this study, the following physical and economic water productivity indicators were used for the estimation of water productivity (Dong *et al*., 2001).

sTable 1, Physical and economic water productivity indicators

S.No.	Water productivity indicator	Physical productivity (kg/m^3)	Economic productivity (ETB/m^3)
1	Total water productivity (WP_T)	$\frac{Y_a}{ER + DW}$	$\frac{Y_a}{ER + DW} * \alpha$
2	Irrigation water productivity (WP_I)	$\frac{Y_a}{DW}$	$\frac{Y_a}{DW} * \alpha$
3	Crop water productivity (WP_C)	$\frac{Y_a}{ET_c}$	$\frac{Y_a}{ET_c} * \alpha$

Where,
Ya= actual harvestable yield (Kg), α = monetary value of harvestable yield (ETB/kg), ER = effective rainfall in mm or m^3, DW = Diverted irrigation water to individuals' command area in mm or m^3, and ETc = crop evapotranspiration.
In addition to the above water productivity indicators relative irrigation supply (RIS), the ration of amount of irrigation water supplied to the crop to the amount of crop irrigation water demand was also estimated for all surveyed irrigation water users to compare crop irrigation requirement and irrigation water supply.

$$RIS = \frac{Irrigation\ supply}{Irrigation\ requirement}$$

Where; RIS is relative irrigation supply,

Estimation of crop evapotranspiration and effective rainfall
The FAO computer programming model CROPWAT 8.0 was used for the estimation of crop evapotranspiration, crop irrigation water requirement and effective rainfall. The model carries out calculations for reference evapotranspiration, crop water requirements and irrigation requirements in order to develop irrigation schedules under various management conditions and scheme water supply. It allows the development of recommendations for improved irrigation practices, planning of irrigation schedules, assessment of production under rainfed conditions or deficit irrigation, drought effects and efficiency of irrigation practices (Kassam and Smith, 2001).
In this study effective rainfall was computed from the mean monthly rainfall data for estimation of total water productivity using the USDA soil conservation service method. The USDA soil conservation service method uses the following equation for calculation of effective rainfall;

$$PE = P_{tot} * \frac{125 - 0.2P_{tot}}{125} \ (For\ P_{tot} < 250\text{mm})$$

$$PE = 125 + 0.1 * P_{tot}\ (For\ P_{tot} > 250mm)$$

Where: PE is effective rainfall (mm) and P_{tot} is total rainfall (mm).
Estimated depth of excess rainfall and crop evapotranspiration was expressed in m^3 by multiplying the excess rainfall depth by the annually irrigated area of selected individual users during the last five production years.

Results and discussions
Irrigation water pricing practices in Awash River basin
Any significant water diversion from Awash River for irrigation purpose requires the approval of Awash basin authority (ABA). ABA has the mandate and power of controlling irrigation systems in the basin up to the primary irrigation canals. Controlling secondary, tertiary and on-farm irrigation canals is the mandate of respective individual irrigation users. ABA is the only one of its kind in Ethiopia that operates with the concept of river basin management. The ABA collects water fees on volumetric basis with an initial objective of covering all cost expenses of the authority. Individual users are charged according to their annual consumption of irrigation water with a charging rate of 3 ETB per 1000 m^3. All legal irrigation water users in the basin are charged 78.18 ETB per hectare per year for the service rendered by the authority in addition to the water fee. Users abstracting water with gravity are additionally charged 5.9198 ETB per hectare per year to cover monthly salaries of gate operators.
Each year a contract is signed between the Authority and each of its clients, and irrigation water use permit is issued. The permit stipulates its expiration date, the amount of water required by each client, means of water abstraction, area to be irrigated, and irrigation period. Once the irrigation season starts, a water request format is prepared by the authority for legal irrigators diverting water from each primary off take structure. Individual irrigators submit their irrigation water demand request to the authority on a weekly basis based on the request format prepared by the Authority. The amount of water diverted to individual users is measured at primary offtake structures of the primary irrigation canals with water measuring staff gauges.
Some small scale irrigation schemes use one offtake structure (single recording gauge) in common and water fee is collected based on their annually irrigated area. Those small scale irrigators (especially in Amibara area) who

do not have access to irrigation water directly from the primary irrigation canal, get access from other users' secondary or tertiary canals. These users face water scarcity problems during low flow or/and high irrigation demand season and excess water is released to their farm during low irrigation demand season.

Vertical water flow measuring staff gauges of standard enameled iron with plated sections located at every primary offtake (PO) structures are used to measure amount of water flow to individual irrigation users. The stage-flow relationship (rating curve) of these flow measuring staff gauges is adjusted every year after the maintenance of primary irrigation canals using current meter. Gate operators are available 24 hours at every primary offtake structure to adjust amount of water flowing to individual users and to take staff gauge readings.

The current irrigation water pricing system in Awash River basin does not have limitations on the maximum extraction rate of irrigation water for upstream users. Consequently there is no way of restricting the amount of water being extracted during the periods of peak irrigation demand. As a result downstream irrigation users suffer from water shortage during low flow and high irrigation water demand periods. Such irrigation water shortage problems are common at Amibara area (middle Awash) for users diverting water through gravity flow located at the lower end tail of the main canal during months of April and May.

Many irrigation water users in the basin abstract water from Awash River either through motor pumps or gravity flow without any permit issuance from the authority. Some users get access to irrigation water either by tampering or abstracting through motor pumps from primary irrigation canals illegally. Such illegal irrigation water users in the basin are charged neither for services nor for the cost of water.

At the end of each Ethiopian budget year letter is issued to individual legal irrigation water users in the basin from ABA including their annual irrigation area (ha), amount of water consumed (m^3), irrigation water charge (ETB), and service charges (ETB) and requested to pay their annual water and service charges through bank account of the basin.

Crop water productivity

Crop water productivity in this study was expressed in terms of the total available water (including both effective rainfall and diverted irrigation water), diverted irrigation water and water lost through crop evapotranspiration. Results of all water productivity values were expressed in physical (kg/m^3) and economic (ETB/m^3) terms.

Minimum, maximum and average values of physical and economic total water productivity (TWP) of cotton, sugarcane and onion are presented in Table 2. Values of average total available water productivity for cotton, sugarcane and onion was 0.16, 7.80 and 1.38 kg /m^3 respectively. During 2005/06-2009/10 production years, sugarcane producers were able to get more production rate per unit of available total water than cotton and onion producers get. But, economic water productivity, measured in terms of gross value per unit of total available water was highest for onion producers with five years average value of 5.179 ETB/m^3.

Table 2. Physical and economic total water productivity

Crop	Physical TWP (kg/m^3)				Economic TWP (Birr/m^3)			
	Min.	Max.	Mean	S.D	Min.	Max.	Mean	S.D
Cotton	0.027	0.516	0.156	0.086	0.230	7.219	1.257	1.125
Sugarcane	4.380	13.500	7.891	2.669	0.044	2.159	1.08	0.474
Onion	1.018	1.811	1.385	0.234	1.628	10.323	5.179	2.801

Excluding the amount of water available from excess rainfall and considering only amount of water diverted to individual irrigation users' offtake structure, irrigators were able to produce 0.2, 11.84, and 2.01 kg of cotton, sugarcane and onion respectively from every m^3 of diverted irrigation water (Table 3). The economic return of every m^3 of irrigation water diverted to individual users' irrigated land was 1.70, 1.63 and 7.67 ETB on average from cotton, sugarcane and onion respectively.

Table 3. Physical and economic irrigation water productivity

Crop	Physical IWP (kg/m^3)				Economic IWP (Birr/m^3)			
	Min.	Max.	Mean	S.D	Min	Max	Mean	S.D
Cotton	0.026	1.104	0.204	0.166	0.097	15.453	1.702	2.190
Sugarcane	0.600	29.505	11.836	6.463	0.060	4.101	1.626	0.967
Onion	1.528	2.674	2.039	0.329	2.444	15.244	7.674	4.142

Table 4 below shows physical and economic crop water productivity of cotton, sugarcane and onion from every meter cube of water lost through crop evapotranspiration during the surveyed five production years. For the production of 0.36 kg of cotton, 15.26 kg of sugarcane and 2.27 kg of onion, one meter cube of water was lost through crop evapotranspiration on average. Gross economic return per unit of crop evapotranspired water was highest for onion followed by cotton.

Table 4. Physical and economic Crop water productivity

Crop	Physical CWP (kg/m^3)				Economic CWP (Birr/m^3)			
	Min.	Max.	Mean	S.D	Min.	Max.	Mean	S.D
Cotton	0.139	0.853	0.357	0.146	1.194	5.659	2.545	0.89
Sugarcane	9.807	18.807	15.261	3.063	1.126	3.009	2.069	0.622
Onion	1.594	2.934	2.269	0.451	2.551	16.722	8.432	4.571

Sugarcane producers' were with the highest physical and lowest economic productivity values from unit of total available, irrigation and crop evapotranspired water during the surveyed production years.

Table 5 indicates the annual and five years average relative irrigation supply (RIS) for cotton, sugarcane and onion crops during the surveyed production years. As it indicates, sugarcane producers were with the lowest five years average RIS value (1.281) compared to cotton and onion producers. This indicates that sugarcane producers divert irrigation water 28% more than the estimated crop water requirement. This result is an evidence that irrigation water users in Awash basin diverts more irrigation water that exceeds the amount of crop irrigation water requirement by 59.9%, 28.1% and 62.4% for cotton, sugarcane and onion respectively. This additional excess irrigation water is beyond the irrigation water requirement of these crops and does not have contribution in production improvement; rather it could be a source of problems related to application of excess irrigation water like water logging and salinity. It also indicates the low irrigation water management level of irrigators in the basin.

Table 5. Annual and five years average RIS for cotton, sugarcane and onion

Crop type	Production year					Five years average
	2005/06	2006/07	2007/08	2008/09	2009/10	
Cotton	1.653	1.477	1.804	1.510	1.552	1.599
Sugarcane	1.481	1.189	1.696	1.095	0.952	1.281
Onion	1.678	1.662	1.559	1.559	1.661	1.624

To evaluate the effect of additional operational cost of motor pumps on water productivity or water use efficiency, relative irrigation supply was compared for the two state owned large scale sugar estates of Metehara and Wonji. These irrigation schemes are more or less under the same management conditions and they divert irrigation water through gravity and motor pumps respectively.

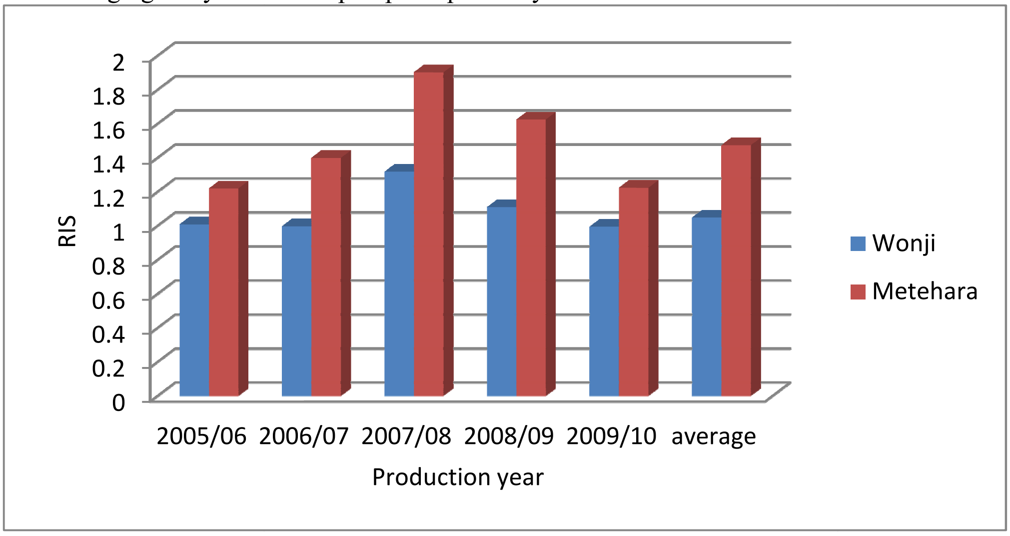

Figure 1. Annual relative irrigation supply of Metehara and Wonji sugar estate farms

Figure 1 indicates the relative irrigation supply comparison of Metehara and Wonji irrigation schemes. RIS of Wonji is almost the same for the surveyed five production years with an average value of 1.048, but that of Metahara varies from 1.218 during 2005/06 up to 1.902 in 2007/08 with an average five years value of 1.473. From this result it can concluded that irrigation schemes with additional operational cost of motor pumps use irrigation water more efficiently than those schemes diverting irrigation water through gravity.

Conclusions and recommendations

Awash basin is the only basin that operates with the concept of river basin management in Ethiopia. Different organizations were established and subsequently replaced to manage land and water resources or only water resources of the basin. Currently ABA is legally delegated by MoWRE to manage water resources of the basin in an efficient, equitable and optimum manner. Irrigation water users in the basin are charged for their water consumption on volumetric basis with a charging rate of 3 ETB/1000m^3 with an additional service charge of

78.18 ETB per hectare per year. The initial objective of pricing irrigation water in Awash basin was to cover the running cost of the authority including monthly salary of employees. The absence of maximum water abstraction limit for users in the basin affects lower end tails users to face water shortage problems during high irrigation demand seasons in middle Awash.

During the surveyed five production years, application of irrigation water and crop production per unit of irrigated land was poorly related with R^2 value of 0.147 and 0.442 for sugarcane and onion crops respectively. In case of cotton, the productivity indicates a declining with increasing irrigation application rate. This kind of relation between crop production and irrigation water application indicates application of excess irrigation water than the amount required by the crops. This is also evidenced by the result of relative irrigation supply which was found to be more than one for all crops considered. Apart from water supply the conditions of irrigation management level also affects land productivity.

Since irrigation water in the basin is distributed and allocated by Awash Basin Authority there is no conflict between legal irrigation water users. Compared with experiences from other countries that are collecting water fees based on volumetric irrigation water pricing method, the charging rate in Awash basin is too low. As a result, the current irrigation water pricing level in the basin does not encourage irrigation water users to consider water price in users annual irrigation water demand, irrigation scheduling, water application rate, crop selection, change in cropping pattern, area expansion, and improve water productivity. This low price level is resulted in low water productivity level, low water management level and high water application rate compared to the irrigation water requirement of crops considered in the basin. Low water management level and high irrigation water application rate in turn may lead to problems related to excess water application like water logging and salinity.

The irrigation water price level currently practiced in Awash Basin was set in 1994 together with the water tariff determinations for other sectors. Since then, it has never changed. The pricing system must be flexible and subjected to changes depending upon socio-economic and environmental circumstances and management objectives. Cost of irrigation water in the basin should be optimized up to a certain level that can cover not only the operation and maintenance as well as the running costs of authority but also that can encourage water users to use water more efficiently (as irrigation water demand management option).

Awash basin authority should have also to set maximum irrigation water extraction rate for upstream irrigation users based on crop type and irrigated land of individual users in order to leave enough water for downstream irrigation users during high irrigation demand periods.

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