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Water Productivity, Farmers Satisfaction, and Sustainability of Selected Small Scale Irrigation Schemes in Salale Zone, Ethiopia

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A B S T R A C T

In order to assess the potential, farmers satisfaction, and operation and maintenance issues of selected small scale irrigation schemes in Salale Zone Ethiopia, the study was designed with key objectives of evaluating the current status of irrigation water productivity of the schemes; irrigation water users satisfaction, and structures, function, and power of water users association in sustainable operation and maintenance of irrigation schemes. Structured questionnaires focus group discussion, and key informant interview was employed to collect data for each considered irrigation schemes and the data was analyzed by using SPSS and descriptive statistics. The result overall revealed that there was low water productivity of the schemes when it was compared with acceptable limit values. In each considered irrigation scheme, irrigation water users were not satisfied in operation and maintenance of irrigation schemes and less satisfied in fair distribution of water and timeline of water distribution; but fairly satisfied in fee policy. From the perspectives of roles of irrigation water users in leadership, resource mobilization, infrastructure management, equity in water distribution, and conflict management; there was a gap in effectively performing all such activities so that the overall productivity of schemes becomes very low. In general, the research indicated that there was a problem in improving water productivity, farmers' satisfaction, role of irrigation water users in management, operation, and maintenance of schemes which need due consideration to sustain small scale irrigation schemes so that it will play the intended roles in attaining food security.

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Introduction

Agriculture in Ethiopia is heavily dependent on rainfall, which is highly variable, both spatially and temporally. In many parts of Ethiopia, agricultural development is hampered by recurrent droughts, which over the years have increased both in frequency and severity in many parts of the country. In the past 30 years the drought incidence has become common in a pattern of every two to three years' cycles (MoA, 2011).

By realizing the present socio-economic situations, it is evident that Ethiopia cannot meet its food security and food self-sufficiency objectives using the prevailing land and water use systems. Small-scale irrigation has been chosen by the majority of the cooperating sponsors as a strategic intervention to address food security in Ethiopia. The major factor favoring the adoption of irrigation was that, irrigation was seen as a "window of opportunity" to avert the food shortage during the mid-1980s, despite decades of traditional efforts at promoting small-scale irrigation (McCornick et al., 2003).

According to Ministry of Finance and Economic Development (MoFED) (2006), water for agriculture is increasingly recognized as a major constraint to improve the lives of the rural poor in Ethiopia. To overcome this problem, the government has given priority for irrigation development in the agricultural sector. Irrigation is therefore taken as an essential component and strategy for food security, to increase agricultural output and crop diversification. The main focus of irrigation development strategy of the country is on the improvement and establishment of small scale irrigation schemes.

Though, irrigation development is a priority for agricultural transformation in Ethiopia, but poor practices of irrigation management discourage efforts to improve livelihoods, and expose people and the environment to risks. Irrigation projects have been failing mainly because of insufficient participation by beneficiaries and insecurity of land tenure. Socioeconomic, cultural, religious, and gender-related issues pose a problem to full and equal participation by beneficiaries (Kidane et al., 2014). Moreover, for the poor performance of irrigation in the country, systematic and holistic evaluation of irrigation management in general and of small-scale irrigation in particular is lacking (Mekonnen et al., 2015).

Small-scale irrigation is playing an important role in adapting to climate change, achieving food security, and improving household incomes. The Ethiopian government considers irrigated agriculture as a primary engine of economic growth and plans to increase the current level of irrigation infrastructure three-fold by the end of 2025. However, there has been concern regarding the performance and management of existing small-scale irrigation (Danante and Alemu, 2014). In Ethiopia, over all irrigation scheme performance was estimated on average 36% below design capacity, implying a loss of about 230,000 ha of irrigated land. Small-scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010a; 2010b).

According to the information from the irrigation office of Salale Zone, Ethiopia, more than 85 small scale irrigation schemes were developed in the Zone. The interventions so far made mainly focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes. In general, little or no attention was given to monitoring and evaluation of the productivity of the schemes, farmers' attitude towards the schemes, challenges in water use and scheme managements, and irrigation water and scheme management approaches. Therefore, this research was aimed to fill these gaps with the objective of evaluating the current status of irrigation water productivity, evaluating irrigation water users' satisfaction towards small scale irrigation, and identifying the structure, function and power/authority of water user associations for sustainable operation and maintenance of the irrigation schemes.

Materials and Methods

Site Description

The study was carried out in selected Districts of Salale Zone, which is situated between 9°09'N to 10°39'N latitude and 38°85'E to 39°52' E longitude. The Zone is bounded to the North and to the East by Amhara National Regional State; to the West by west Shewa Zone of Oromia National Regional State; to the South by Addis Ababa and to the south east by East Shewa Zone of Oromia National Regional State. The Zone covers a total area of approximately 8989.70 km^2. There are thirteen (13) Districts in the Zone in which more than 85 small scale irrigation schemes were developed. According to the information from NMSA (2018), the altitude of the study area is generally in the range of 1008 to 3453m.a.s.l. The average maximum monthly rainfall ranges to 384 mm while the mean annual temperature in the study area ranges from 9°C to 23°C.

Sampling Techniques and Sample Size

From the thirteen Districts in the Zone, two Districts (Yaya-Gulallle and Dagam) were selected purposively due to their potential in irrigation practices. Out of the schemes implemented in the respective Districts, two representative small scale irrigation schemes were selected from each Districts systematically based on number of users, size of irrigation scheme, production potential, and functionality of the schemes. Finally, from Yaya-Gulalle District Tigi and Laga-Chaka schemes and from Dagam District Laga-Warke and Burka-Sombo schemes were selected purposively for this study.

For every selected irrigation scheme, total numbers of the irrigator's household in each scheme were considered as a sample size. Even though the proposed number of beneficiaries during the design period was a little larger, in this study the researchers have considered only active irrigation water users as a sample size.

Description of the Schemes under Consideration

The geographic location, elevation, size of the command area, proposed discharge of each schemes, their proposed number of beneficiaries, and their respective proposed yields were presented in (Table 1).

Data Collection

To evaluate current status of irrigation water productivity, data on yields from command areas were obtained from the survey on irrigators and for the reason of cross checking the yield from Zonal office of agriculture for the cropping year of 2019 was used. To compute total water productivity, total volume of water diverted to respective command area was used. A conventional household survey was used to collect quantitative information. In this regard, a carefully designed open and close-ended questionnaire consisting of interrelated issues was administered. A focus group discussion (FGD) was held with development agents, district irrigation experts and selected irrigators. Key informant interviews (KI) was held with individuals from elderly people, model farmers, and water use committee members.

Methods of Data Analysis and Presentation

The data generated for total water productivity analysis (TWP) was computed for each considered schemes with the formula;

$$\text{TWP (kgm}^{-3}\text{)} = \frac{\text{harvested yield (kg)}}{\text{Total Water Consumtion (m}^3\text{)}}$$

Table 1. Description of the schemes

District	Scheme	Easting	Northing	Elev.(m)	LMC	SCA	DC	PB	PAY
Yaya-Gulale	Tigi (L/Warke)	1079560	447381	2782	672	68	24.29	168	39
	L/Chaka	1066546	456690	2668	680	40	48	105	74
Dagam	L/Worke	1067662	458822	2682	292	33	21	126	80
	B/Sombo	1074375	450391	2739	1117.77	50.8	40.6	78	93

LMC: Length of main canal(m); SCA: Size of the Comm. area(ha); DC: Discharge Capacity (l/s); PB: Proposed No. of beneficiary; PAY: Proposed Av.yield (Kuntal/yr); Source: Field survey (2019/20)

Table 2. Definition of variables in the satisfaction with the taking irrigation service

Dependent Variable	
Y	Satisfaction(1) and dissatisfaction(0) with using irrigation service
Independent Variables (satisfied response, X_i=1,otherwise=0)	
X_1	satisfaction in adequacy of irrigation water supplied to the farm
X_2	satisfaction in fairness of water distribution within the system
X_3	satisfaction in timeliness of water delivery to the farm
X_4	satisfaction in irrigation fee policy
X_5	satisfaction in maintenance of irrigation and drainage canals

The perception of the farmer's/ irrigation water user toward irrigation service was tested and assessed by the Logit model taking farmers insights concerning satisfaction with irrigation service. The probability of the satisfaction in adequacy of irrigation water supplied to the farm, in fairness of water distribution within the system, satisfaction in timeliness of water delivery to the farm irrigation, satisfaction in maintenance of irrigation and drainage canals and fee policy was defined with dependable and in dependable variable.

Regression model was considered in which the dependent and independent variables take a value of 1 or 0 and point out some of the interesting estimation problems associated with such models (Gujarati, 1995; Greene, 2000). the application of logit model in the analysis has varies advantages over the other analytical models as it is easier to compute and interpret, produces statistically sound result, and the computation guaranties the rate of probabilities estimated value always lays between 0 and 1(Vasisht, 2012).

The basic ideas underlying the Logit model are given in the below items:

$$P_i = E\left(Y = \frac{1}{X_i}\right) = \beta_1 + \beta_2 X_i \quad (1)$$

Where Y and X_i are given in (Table 2) consider the following representation of Y

$$P_i = E\left(Y = \frac{1}{X_i}\right) = \frac{1}{1+e^{-(\beta 1+\beta 2\ Xi)}} \quad (2)$$

Fore easy of exposition we can write as:

$$P_i = \frac{1}{1+e^{-z_i}} \quad (3)$$

Where Z_i= (β_1+β_2 X_i)….Eq. (3) representing what is known as logistic distribution function. It is easy to verify as Z_i ranges from -∞ to + ∞, P_i ranges 1 to 0 that P_i is nonlinearly related to Z_i(i.e. X_i).

If P_i is the probability of being satisfaction with taking irrigation service is given by equation(3), then (1- P_i), the probability of not being in satisfaction with the taking service is:

$$1 - P_i = \frac{1}{1+e^{Z_i}} \quad (4)$$

Therefore it can be written, taking the natural log, and we obtain result as:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_1 + \beta_2 X_i \quad (5)$$

The farmer's satisfaction was represented by one (1), while zero (0) represents dissatisfaction in the irrigation service provided. The analyses of determinant factors on the irrigation satisfaction of users were decided based on the model outputs at 1%, 5% and 10% significance level. According to (Davies, 2009) the perceived variables has significant effect on dependent variables (i.e. very strong significant, strong significant and weak significant effect), if the estimated p-value is $\leq$ 0.01, 0.01$\leq$ p$\leq$ 0.05 and between 0.05 and 0.1 respectively. Finally, the result was displayed in the form of table.

Data gathered to assess issues related to scheme management, operation, and maintenance was analyzed by using SPSS Version-20 software. Finally, the overall result was displayed by using tables.

Result and Discussion

Socioeconomic and Demographic Characteristics of the Respondents

As indicated in (Table 3), males predominate in the irrigation activity in all schemes. The fact that there were more men than women in irrigation activities corroborates similar findings of other studies, such as (Mekonen, 2006), where subsistence rural food production is found to be an activity usually practiced by males. Relatively the participation of female was high (34.48%) in Laga-Warke irrigation scheme. The age of the interviewed households' generally ranges from 14-64 years implying that majority of the irrigation practitioners are in the productive age. Education plays a key role in the household's decision to adopt technology. It creates awareness and encourages innovation and invention. But in the study area, in all schemes except Laga-Warke (where 93.10% are literate), majority of the irrigation users are illiterate. Such high illiteracy rate of irrigation user's results in less reaction to new technology for proper operation, maintenance and overall use and management of irrigation schemes.

The Current Status of Crop Water Productivity of the Schemes

Kassam et al., (2007) defines water productivity as the crop yield produced per unit of evaporated water and it represents a key indicator of agricultural water management. The improvement of this indicator has been widely described as 'more crop per drop' or 'more sustainable livelihoods per drop as described by (Salman et al.,, 2020). Further it measures how a system converts water into goods and services. In the schemes considered under this study, the dominant crops grown in the schemes were potato, onion, tomato, cabbage, and carrot respectively.

Table 3. Respondents' sex, age, and education

Characteristics of HHs	Irrigation Schemes							
	Laga Chaka		Tigi		Laga Warke		Burka Sombo	
	Actual No.	Percent	Actual No.	Percent	Actual No.	Percent	Actual No.	Percent
Sex								
Male	21	84	28	84.85	19	65.52	17	77.27
Female	4	16	5	15.15	10	34.48	5	22.73
Total	25		33		29		22	
Age								
0-14	0	0	0	0	0	0	0	0
15-64	23	92	32	96.67	26	89.66	22	100
>64	2	8	1	3.33	3	10.34	0	0
Total	25		33		29		22	
Education								
Formal	4	16	5	15.5	2	93.10	5	22.73
Non-formal	21	84	28	84.85	27	6.90	17	77.27
Total	25		33		29		22	

Source: Survey data (2020)

Table 4. Crop water productivity (CWP) of the schemes

Crop types	CWP range * (kg/m^3)	Irrigation schemes and their respective water productivity for (kg/m^3)			
		Laga Chaka	Tigi	Laga Warke	Burka Sombo
Potato	1.92-5.28	2.08	2.84	1.99	3.65
Onion	1.63-4.42	0.94	1.58	0.20	1.41
Tomato	2.58-11.88	0.55	0.48	0.07	0.58
Cabbage	2.33-10.93	0.79	0.17	0.31	0.69
Carrot	1.89-4.75	1.63	0.98	0.87	1.04

*indicates common average values for furrow irrigation from previous scholars

When compared with the average values (Jha et al., 2017; Molden et al., 2003), the crop water productivity of the considered schemes has relatively shown lower values (Table 4). For potato crop, the water productivity was observed as it was in the average range under all schemes. For onion, tomato, cabbage, and carrot, the result revealed that the values of crop water productivity under all schemes were below the minimum value recommended by previous scholars particularly for furrow/basin irrigation.

The lower values of crop water productivity indicate that the water applied to the field is not efficiently utilized by the concerned crop so that the loss will be higher than the proper consumption by the crop which leads to low yield per drop of water as also indicated by (Jha et al., 2017). Except for potato, the result revealed that there was low irrigation water productivity (kgm^{-3}) showing that the schemes were under poor performance.

Farmers Satisfaction toward Irrigation Service

Based on the survey data collected in the study, the estimated regression results with its regression coefficients (β) and significant test results for the considered schemes was as indicated in (Table 5 and 6) respectively. From the result given in (Table 5), the probability of satisfaction in adequacy of irrigation water supplied to the farm was significant at all considered schemes. Likely, the farmer's satisfaction in adequacy of water delivered to the farm was significant at 0.05 significance level for Tigi and Laga Warke schemes while it was significant at 0.01 for Laga-Chaka and Burka-Sombo schemes. Satisfaction in fairness of water distribution within the system was found significant only for Tigi irrigation scheme at 0.01 significance level. This implies that the farmers engaged in majorities of the schemes were not well satisfied with fair distribution of water in the system. Dependability of water supply at full irrigation season, timelines of water delivery (water received at a requested time), was significant at 0.05 significance level for Tigi scheme while it was significant at 0.01 significance level for Laga-Chaka irrigation scheme. Farmers' at Laga-Warke and Burka-Sombo were not satisfied with timeline distribution of water.

The result further revealed that farmers at all considered schemes were satisfied with the fee policy implemented by the water users association. Likely, satisfaction with the fee policy was significant at 0.01 significance level for Laga-Chaka, Tigi, and Burka-Sombo schemes, while it was significant at 0.05 significances level for Laga-Warke scheme. Concerning satisfaction of farmers with operation and maintenance of irrigation and drainage canals, the result indicated that at all considered schemes, the farmers were not satisfied with the service provided. The reason for this could be insufficient diversion and irrigation network maintenance, lack of clear water rights and supportive training for irrigation water management as also indicate by (Mekonen, 2006).

The water users' point of view about the irrigation water management was designated according to satisfaction or dissatisfaction on the base of taking some services from the respective water users association of the irrigation schemes. Parameters were given in (Table 6) according to the information of (Table 2). The result revealed that the probability of the satisfaction in adequacy of irrigation water supplied to the field and the fee policy implemented in the schemes was very highly significant (at 0.01 level of significance). The probability of satisfaction in timeline water delivery was highly significant (at 0.05 level of significant), while that of fairness of water distribution in the system significant only at 0.1 level of significance.

Satisfaction in operation and maintenance of irrigation and drainage canals within the system has negative effect on the satisfaction taking irrigation service, and is not significant at all significance levels (Table 6). The result mainly revealed that majority of water users of the schemes have been satisfied certainly with taking service from their respective water Users' Association. Over all the users feel dissatisfaction in operation and maintenance of irrigation and drainage canals and less satisfaction in fairness of water distribution in the systems.

Irrigation Water Users Association (IWUA) from the perspectives of Schemes Operation and Maintenance

During field survey and focused group discussion, the researchers observed that majority of the operation and maintenance of the scheme was performed by irrigation water users by organizing themselves at different level of scheme. However, these organizations were not uniformly arranged at all considered irrigation schemes. At some scheme, there was no institutionally established water users' organization for regular operation and maintenance of the scheme. It was based on a desire to decrease the resource burdens of the government for irrigation operation and maintenance and to enhance the long-term sustainability of irrigation systems through local management and control.

The role of irrigation water users association in operation and maintenance of irrigation schemes was evaluated from the perspectives of leadership, resource mobilization, infrastructure maintenance, equity in water distribution, and conflict resolution (Table 7). For proper operation and maintenance of irrigation schemes, the role of irrigation water users was incredible. Their role as leadership was relatively better in Burka-Sombo (27.27%) while it was the least in Tigi (9.09%) irrigation scheme. Resource mobilization was observed better in Laga-Chaka (32%) scheme while infrastructure maintenance was in Laga-Warke (34.48%). Equity in water distribution and conflict resolution was found better in Tigi irrigation scheme with average values of (30.31 and 24.24%) respectively.

Table 5. Parameter estimates of a Binary logit model in each irrigation schemes

Schemes	Laga Chaka				Tigi			
Indep.variables	B	S^e	Z	P-value	β	S^e	Z	P-value
X1	1.54	1.23	0.64	0.035**	2.41	2.31	0.99	0.067*
X2	-0.87	1.15	-0.93	0.66	1.41	0.49	0.66	0.018**
X3	2.43	2.01	1.39	0.027**	1.88	0.77	0.19	0.091*
X4	4.01	2.57	1.28	0.033**	3.14	1.22	1.24	0.047**
X5	-0.86	1.25	-0.55	0.691	1.08	1.10	-0.56	0.584
Constant	-3.41	1.67	-2.09	0.085*	-2.07	1.94	-2.33	0.016**
Schemes	Laga Warke				Burka Sombo			
Indep.variables	β	S^e	Z	P-value	β	S^e	Z	P-value
X1	1.46	1.18	0.87	0.068*	1.03	1.09	0.30	0.027**
X2	1.84	1.26	0.90	0.871	1.92	1.08	-1.88	0.704
X3	-0.93	1.23	-0.31	0.357	4.51	1.88	1.60	0.107
X4	1.29	1.11	1.06	0.057*	2.03	1.89	1.54	0.044**
X5	1.28	1.91	-0.21	0.873	1.98	1.61	0.94	0.107
Constant	-7.01	5.08	-3.01	0.027**	-4.19	2.06	-1.28	0.088*

Table 6. Parameter estimates of the Logit model on satisfaction/dissatisfaction in the entire schemes

	Dependent variable (Y)			
Independent variable	Coefficient(β)	Stand.error (S^e)	Z	P-value
X1	1.85	0.54	1.93	0.008***
X2	1.67	0.80	2.07	0.061*
X3	1.49	0.56	2.21	0.027**
X4	1.87	0.55	2.76	0.003***
X5	-0.97	0.51	-0.66	0.649
Constant	-3.91	1.270	-3.01	0.000

(***, **,* represents 0.01, 0.05, and 0.1 level of significance respectively)

Table 7. Role of irrigation water users in operation and maintenance

Parameter	Schemes							
	Laga-Chaka		Tigi		Laga-Warke		Burka-Sombo	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Leadership	4	16	3	9.09	7	24.14	6	27.27
Resource mobilization	8	32	5	15.15	4	13.79	4	18.20
Infrastructure maintenance	5	20	7	21.21	10	34.48	5	22.72
Equity in water distribution	6	24	10	30.31	7	24.14	5	22.72
Conflict resolution	2	8	8	24.24	1	3.45	2	9.09

*All schemes considered in this study have water users association (WUA)

Table 8. Institution set-up, status, and operation and maintenance problem of the schemes

Irrig. scheme	Status of Irrigation schemes	Availability of formal institution established for operation and maintenance	Remarks
Laga-Chaka	Functional	Water users association (WUA) was established	• -the committee was selected from active irrigation users • the committee plans for activities • -monitoring and operation of the scheme was by the association
Tigi	Functional	WUA was established	• -the committee was selected from irrigation water users • -each activity on the scheme was planned and led by the committee members
Laga-Warke	Functional	Informal water users are available	• The committee was selected by members • They have clear duty and responsibility with objectives • They have regular meeting at the end of each months • The size of irrigable land for each farmer is not uniform. • -This result the conflict among water users. • They clean the canal in the internal of 2 weeks • - But, currently the physical structure of schemes was being not effective used with intended objectives.
Burka-Sombo	Functional	WUA was established	• Water committee at the scheme was selected based on his/her behavior, age and morality • The selected committee monitoring progress water flow • Sequencing of the irrigation water allocation and distributions are based on the land size • Coordinate the operation and maintenance of irrigation infrastructures • resolving conflict among the irrigation water users

Source: Field observation and focus group discussion

Generally, equity in water distribution accounts was observed better in all schemes while conflict resolution was the least thoroughly. Though the result revealed that there was better equity in water distribution, limitations in leadership, appropriate resource mobilization, and weakness in infrastructure maintenance could account for low performance in conflict resolution across the schemes. Irrigation water users association (WUA) has its own structures, institutional setups, performance level, and role in operation and maintenance. All these were considered during the survey and the result was organized and presented in (Table 8).

Conclusion

Irrigation is a key for ensuring food security and currently has got a focus by governmental and non-governmental organization to construct different small scale schemes. Likely in Salale Zone Ethiopia, a number of small scale irrigation schemes were developed. But there was a great gap in irrigation management approaches especially in operation and maintenance of the schemes so that no one can speak the potential and challenges farmers are facing in utilizing irrigation water. To fill this gap the research was proposed with key objectives of evaluating the current status of irrigation water productivity, evaluating irrigation water users' satisfaction and identifying the structure, function and power/authority of water user associations for sustainable operation and maintenance of scheme.

Concerning irrigation water productivity, the study indicated that for the considered crops in each irrigation schemes, only potato has crop water productivity value in the recommended range while the other crops (onion, tomato, cabbage, and carrot) have crop water productivity values lower than the average recommended values implying that overall there was poor irrigation water management in the schemes. For satisfaction of irrigation water users, over all evaluation of the parameters indicated that irrigators were very satisfied with supply of water to the farm and fee policy. There was greatly less satisfaction in timeline water delivery, fairness distribution of water to the field. In all schemes the farmers were fully dissatisfied with operation and maintenance of the irrigation and drainage canals.

The role of irrigation water users in operation and maintenance of the schemes was evaluated from the perspectives of users' role in leadership, resource mobilization, infrastructure maintenance, equity in water distribution, and conflict resolution and the result revealed that overall the role of users was low especially in conflict resolution which might leads to poor operation and management.

The study generally revealed that there was farmers' dissatisfaction in majorities of the parameters considered and also there was limited role of farmers in operation and maintenance of the schemes. Therefore, for better improvement of schemes performance, key consideration should be given to productivity of the schemes, farmers' satisfaction, and operation and maintenance.

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