Original Article
ISSN (Online): 2456-8651

International Journal of Engineering Science Technologies
September-October 2024 8(5), 20–32

ASSESSMENT AND TECHNICAL CONSTRAINT IDENTIFICATION OF SMALLHOLDER IRRIGATION PUMP IN ARSI AND EAST SHEWA ZONE, OROMIA

Bayan Ahmed [1], Asnake Tilaye [1]

[1] Oromia Agricultural Research Institute, Asella Agricultural Engineering Research Center, P.O Box 6, Asella, Oromia, Ethiopia

Received 20 August 2024
Accepted 21 September 2024
Published 28 October 2024

Corresponding Author
Bayan Ahmed, bayahm@gmail.com

DOI 10.29121/IJOEST.v8.i5.2024.641

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

Efficient irrigation begins with properly installed and maintained pumps, motors, and engines. For this, the study was conducted on potential irrigation pump users of the Arsi and East Shewa zones with the objective of identifying the technical constraints of smallholder irrigation pump users. Doddota from Arsi and Dugda and Bora woreda from the East Shewa zone were selected. 211 samples size from 2321 pump users were used for data collection. The constraints listed by respondents, like pump damage, pump cost, long priming, and fuel, were the most common bottlenecks in pump irrigation schemes. Pump damage was positively correlation with use of un-recommended suction and delivery head, age of pump, long priming time and continues operation time but negatively correlation with pump maintenance, experience in irrigation farming and educational level of the household. Long priming and fuel consumption was positively (+Ve) correlation with use of un-recommended suction and delivery head, age of pump, operation time and pump size. From the existing pump type respondent responses, KAMA pumps were highly available on the market, vulnerable to damage, and had sufficient spare parts with values of 60.66, 64.45 and 44.08%, respectively. The lowest were Cushion their values were 1.42%, 3.32% and 3.78%, respectively. The respondents also reply, due to absence of governmental pump maintaining organization, cost of maintenance at local and private garage were very expensive (68.25%) and expensive (26.07%). This makes another problem on small holder irrigation pump. Therefore, it is recommended to government to add pump maintaining structure at engineering center which serves' closely to scheme users and providing regular training on maintenance checklist. It is also recommended for engineering and socio-economic researchers to conduct research collaboratively to assess the gap frequently for other kebele pump user and technical performance evaluation for pump that have problems.

Keywords: Constraint, Delivery Head, Suction Head, Irrigation, Pump, Poverty

1. INTRODUCTION

Increasing agricultural productivity through irrigation technologies is recognized as an effective way to improve smallholders' livelihoods and food security in developing countries Tesfaye et al. (2021). Smallholder irrigation expansion would significantly increase agricultural production and reduce food insecurity and poverty levels in East Africa. The adoption of small-scale irrigation technology had unprecedented advantages for smallholder farmers to reduce poverty. It increases use of available water sources to get higher income and improves the livelihood of farmers Mohammed & Shallo (2020) Teha & Jianjun (2021). , and Mume et al. (2023). Use of small-scale irrigation (SSI) technology has significant potential to increase crop productivity in Sub Saharan Africa (SSA). Pumped irrigation systems are one of the technologies increasingly being used by smallholder farmers Kamwamba et al. (2016). Recently, individual irrigation technologies such as different motorized pumps, drip and sprinkler, treadle pumps, rope and washer pumps are being promoted. Adoption of these technologies and expansion of smallholder irrigation however face a number of challenges Kamwamba et al. (2016), Teha & Jianjun (2021).

Currently, government of Ethiopia put wheat initiative plan in structural, economic and sectorial reforms, for food security, raw material for the agro-industry, import substitution that transits to export and job creation along the value chain Effa et al. (2023). With high potential demand to irrigation pump technologies, still there are number of problems in selection for agricultural production improvements Teha & Jianjun (2021). Lack of access to appropriate irrigation technologies, improved agricultural inputs, reliable markets, finance and credit services, and research support; poor transport and communication infrastructures; poor irrigation water management; poor extension systems; and the overdependence on national governments, NGOs and donors for support were some of the problems Nakawuka et al. (2018).

Efficient irrigation begins with properly installed and maintained pumps, motors, and engines. Equipment problems and management problems tend to go hand in hand. Equipment that is badly designed or poorly maintained reduces the irrigator’s degree of control over the way water is applied. Problems like irregular water distribution and inadequate pressure make it impossible to maintain correct soil moisture levels, leading to crop stress, reduced yields, wasted water, runoff, soil erosion, and many other problems Morris et al. (2006). Conflict between members of Farmers Irrigation Water Use Association (FIWUA), unavailability and lack of access to spare parts, topography of the district, irrigation technology technician and lack of skill were among the constraining factors found to hinder water pump irrigation technology adoption and use Teha & Jianjun (2021).

Examining those constraints and planning to solve accordingly is one of the ways that the government and NGOs could address. From this critical assessment, this study was conducted with the objective to assess technical constraint identification problem of smallholder irrigation pump user at Arsi and West Arsi zone of Oromia region.

2. MATERIALS AND METHODS

2.1. DESCRIPTION OF THE STUDY AREA

Figure 1

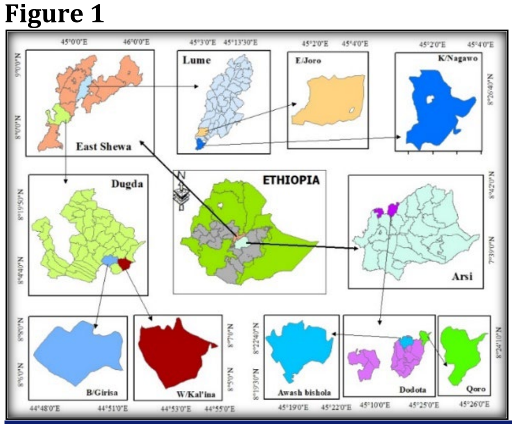

Figure 1 Study Area Map

The study was conducted at Doddota district from Arsi zone and Boru, and Dugda district from East Shewa zone depending on high potential user of irrigation pump.

2.2. METHOD OF SAMPLING AND DATA COLLECTION

To achieve the research objective primary and secondary data collection technique was applied. Primary data was collected from the sample of rural households using a structured questionnaire and secondary data was collected from zonal and district level offices of published and unpublished materials, reports, proceedings and statistical abstracts about the study area. The cluster-based samplings technic were followed to collect from districts expert and user of water pump members. All district nominated expert were interviewed. But for irrigation house hold user the sampling technique were used as stated in equation (1)

$$n= \frac{N}{1+N(e)^2} = 187 \quad (1)$$

Where: n = is the sample size,

N = is total size of Kebele water pump user and

e = the level of precision it is 7%

Samples from each kebele were proportional to the population were determined as stated by (Bowley, 1925)

$$N_i= \frac{(Ni)(n)}{\sum Ni} \quad (2)$$

where,

ni is the sample to be selected from the ith kebele; Ni The total population living in ih kebele; ∑Ni The summation of the population in the six selected kebeles; n— Total sample size for the district.

Table 1

Table 1 Manufacturer Pump Capacity

Inch No	Pump Name and model	Suction Head (m)	Total Head (m)	Discharge (m^3/h)	Priming Head	Pump Weight (kg)	Fuel consuption (l/hr)
2	Kushion (kd300)	8	32		7.5m/150s	50.8	
	Honda	8	32			50.8	
	KAMA (Kdp20)	8	21	22	80s/4m	35	0.342
	Robin	8	46	36		25	
	Eagle (EG150)	8	23	26		23	
3	Kushion (kd300)	8	25			53.8	1.4
	Honda	8	25			53.8	
	KAMA (Kdp30)	8	29	30	120s/4m	52	0.339
	Robin	8	32	60		28	

	Eagle (EG200)	8	25	33		25	
4	Kushion (kd300)	8	36				
	Honda	8	36				
	KAMA (Kdp40)	8	40	46	180s/4m	69	0.334
	Robin	8	46				
	Eagle (EG200)	8	34				

2.3. STATISTICAL ANALYSIS

Data collected through irrigation pump user interview were analyzed by SPSS software package using descriptive statistical such as frequency, percentage; maximum, minimum, mean and standard deviations were used.

3. RESULTS AND DISCUSSIONS

Population and sample size of household irrigation pump user

The total number of irrigation pump user from Awash, Koro Dagaga, Koka Nagawo, Ejersa Koro, Bekela Girisa and Wolda Qellina were 2,321 and 187 sample size were calculated. But to minimize the error in contigance 22 samples were included. Totally 211 samples were used for analysis Table 2.

Table 2

Table 2 Number of Sampling Respondant from Two Zone

Zone	District	Kebele	Population size	Sample size
Arsi	Dodota	Awash	750	61
		Koro Dagaga	338	34
East Shewa	Lume	Koka Nagawo	380	30
		Ejersa koro	200	20
	Dugda	Bekela Girisa	320	33
		Wolda Qellina	333	33
Total			2,321	211

3.1. DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

91.9% of respondent were male and 8.1% were female Table 3. The education level of respondent for grade completed was 32.7%, 59.2% can read and write and only 8.1% were uneducated. Most of the respondents have very good experience in irrigation agriculture about 81.1%. The major crops produced during irrigation season were - onion, tomato, wheat, maize and papaya have taken rank orderly.

Table 3

Table 3 Socio-Economic and Demographic Characteristics of Respondents

Variables	Dummy	Frequency	Percent (%)
Gender	Male	194	91.9
	Female	17	8.1
Educational level	Uneducated	17	8.1
	Read and write	125	59.2
	Grade completed	69	32.7

Irrigation agricultural experience	Very good	171	81.1
	Good	40	19
Major crop produced by irrigation	Onion	55	26.1
	Potato	3	1.4
	Wheat	18	8.5
	Tomato	30	14.2
	Maize	32	15.2
	Onion and tomato	17	8.1
	Maize and papaya	35	16.6
	Wheat and onion	8	3.8
	Wheat and tomato	12	5.7

Source Survey study, 2023

3.2. LAND ALLOCATION AND FAMILY SIZE OF RESPONDENT HH

The minimum and maximum lands allocated for irrigation were 0.25 and 5 ha respectively with mean of 1.24 ha Table 4

Table 4

Table 4 Family Size and Land Allocation

	N	Minimum	Maximum	Mean	Std. Deviation
Total family size	211	1	10	4.78	2.27
Total cultivated land (ha)	208	0	5.00	1.40	1.07
Land allocated for irrigation (ha)	208	.25	5.00	1.24	1.13
Total land (ha)	207	.25	6.00	2.26	1.41

Source Survey study, 2023

3.3. METHOD OF IRRIGATION AND LIMITING PUMP USE

Furrow irrigation was used, by using pump as water lifting. Three inch (65.9%) and four inch (27.5%) pumps were mostly used by the community. This indicated financial of HH, fuel cost and price of pump limited to use large size of pump.

Table 5

Table 5 Water Lifting Pump and Limiting Factor

Variables	Dummy	Frequency	Percent (%)
Method of irrigation to use	Furrow	211	100
Pump size used	3 inch	139	65.9
	4 inch	58	27.5
	6 inch	10	4.7
	8 inch	4	1.9
Limiting factor for pump user	Fuel	127	60.2
	Pump	63	29.9
	Pipe	6	2.8
	Hose	1	0.5
	Hose pipe and fuel	6	2.8
	Pump and fuel	8	3.8

Source Survey study, 2023

3.4. IRRIGATION WATER SOURCE

Four water sources were used to irrigate field. From this, perennial rivers shared 65.4%, irrigation canal 12.3% and bore wall 19.4% Figure 2. This water was pumped from different water depth. The water sources that have depth of water below 8m are about 84.8% and the rest are greater than 8m depth Figure 2.

Figure 2

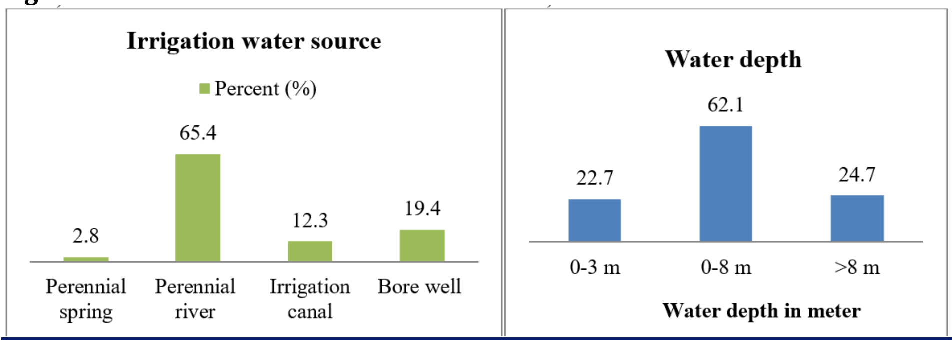

Figure 2 Water source (a) and Depth of Water Pump (b)

3.5. ON FARM PRACTICE OF FARMERS WITH PUMP OBSERVATION

The farmer's response on pump suction practice on different head was tabulated in Table 6 below. From this table the suction head user above 8m were 9%. This show, user were using above recommended suction head of manufacture. This resulting temperature rise, more fuel conception, low live span of pump, long priming.

Table 6

Table 6 Farmers Response on Pump Suction Practice

Variables	Dummy	Frequency	Percent (%)
Suction head of HH pump	<3 m	39	18.5
	3-8 m	153	72.5
	9-12 m	18	8.5
	13-16 m	1	0.5
Dalliance in delivery when suction head greater than 8m	Yes	182	86.3
	No	29	13.7
Priming time of pump too long	Yes	177	83.89
	No	34	16.11
Time take to complete priming	2-5 min	46	21.8
	6-10 min	22	10.4
	11-15 min	22	10.4
	>15 min	112	53.1
Cause of long priming	Pump is far from water source	22	10.4
	Delivery head too high	3	1.4
	Leakage of suction line	16	7.6
	Too freeze	1	0.5

	Size of pipe and pump capacity not fit	4	1.9
	All	24	11.4
Observations of pump at priming time on pump and pumping unit	Temperature	2	0.9
	Fuel combustion	32	15.2
	Relief valve	15	7.1
	Temperature, fuel combustion and over load	33	15.6
	Total	82	38.9
	System	129	61.1

Source Survey study, 2023

Correlation effect of fuel conception: As responded response fuel conception was negatively correlated with irrigation interval, education levels and highly significant deferent at ($p<0.01$). However, positively correlated with manufacturer's oil and lubrication servicing time and large suction head Table 7

Table 7

Table 7 Correlation Effect of Fuel Conception

		Irrigation interval	Educational level	Land allocated for irrigation	delay in delivery head for greater suction	Manufacturer's oil and lubrication servicing time
Fuel consumption	Corr	-.457**	-.335**	.171*	.192**	.171*
	Sig.	0	0	0.02	0.009	0.019

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Source Survey study, 2023

Correlation effects on pump priming: Priming time of pump was positively correlation with fuel conception, suction head, pump size, delivery head and age of pump Table 8 Also priming time was highly significant different at ($p\leq 0.01$) with size of pump. These show large size pumps have long prime time than small size pump. This result agrees with manufacturer manual Table 1

Table 8

Table 8 Pump Priming

		Fuel conception	Pump size	delay in delivery head due to greater suction head	Delivery head	Age of pump
Priming time of pump	Corr.	0.77	.517**	0.146	0.64	0.405
	Sig.	0.48	0	0.179	0.59	0.338

**. Correlation is significant at the 0.01 level

Source Survey study, 2023

The operation time of pump: Average mean of operation time for 3", 4"and 6" pump were (7.28, 7.09 and 5.8) hr/day and mean age of pump were (5.56, 4.34 and 4.8) years respectively Table 9 Three-inch pump had long operation time and age.

Table 9

Table 9 Age of Pump and Operation Time

Inch of pump used		Pump age in year	Operation time in (hr/day)
3	Maximum	16	12
	Minimum	1	4 hr
	Mean	5.56	7.28
	Std. Deviation	4.16	2.47
4	Maximum	15	16
	Minimum	1	2
	Mean	4.34	7.09
	Std. Deviation	3.723	3.79
6	Maximum	11	> 10 hr
	Minimum	3	6.1-8 hr
	Mean	4.8	5.8
	Std. Deviation	2.394	0.632

Source Survey study, 2023

Price of pump

One of the limiting factors to use pump was increment of pump cost from time to time. The most water pump used by farmers were 3-inch pump. The minimum and maximum costs were 3,000 and 40,000 birr respectively Table 10

Table 10

Table 10 Price of pump in (Ethiopian Birr)

Pump inch	Maximum	Minimum	Range	Mean
3	40,000	3,000	37,000	16,833.33
4	70,000	7,000	63,000	29,910.71
6	4,60,000	35,000	4,25,000	3,75,000.00

Source Survey study, 2023

Farmer pump maintenance schedule check list perform

About 30.81% of respondents from four kebeles were not following the daily/monthly/annually pump maintenance checklist. The highest percent of pump maintenance checklist follower were from two Kebele of Dugda district (Bekele Girisa and Wolda Kellina). The lowest were Bora district (Koka and Ejera) kebele Table 11

Table 11

Table 11 Respondent of Maintenance Checklist Follower in Selected Kebele

Variables	Dummy	Respondents' Kebele					
		Awash	Koro Dagag a	Koka Nagaw o	Ejers a koro	Bekel a Giris a	Wolda Qellin a	Total
Daily/monthl y/annually pump		14.22	12.32	6.64	4.74	15.64	15.64	69.19

maintenance checklist								
	No %	14.69	2.37	7.58	4.74	0.95	0.47	30.81
Maintenance time	Periodically %	15	12					
	Randomly %	46	16					
Maintain pump during live time	Yes %	14.22	12.32	6.64	4.74	15.64	15.64	69.19
	No %	14.69	2.37	7.58	4.74	0.95	0.47	30.81
Duration of pump before first maintenance	0-3 month	11.85	0.95	2.84	3.32	5.21	1.9	26.07
	4-7 month	4.27	2.37	5.21	0.95	0	7.11	19.91
	8-11 month	0	0.95	1.9	0.95	5.69	1.9	11.37
	>= 1yrs	0	0	0	0.95	2.37	0	3.32
	Oil color	13.27	8.06	5.21	4.27	3.32	5.21	39.34
Changing engine oil	After 2 weeks	12.8	1.42	11.37	7.58	11.85	13.27	58.29
	After 3 weeks	1.9	2.37	0.95	0	3.79	2.37	11.37
	After one month	8.06	10.43	2.37	2.84	0	0	23.7
	Depending on level of oil and color change	6.64	0	0	0	0	0	6.64

Source Survey study, 2023

Determining the engine oil change with irrigation period and working time

From Table 12, Farmers engine oil change was calculated from irrigation period, working hour and time of engine oil change. Changing engine oil after two week were below and after four week were above manufacturers' recommendation of 50 hour (Lynne, 2006). But after three week were close to recommendation.

Table 12

Table 12 Farmers Engine Oil Change

Irrigation period per week	Average working hour per day	Time of engine oil change	Farmers engine oil change	Manufacturer engine oil change
2	8	After 2 week	32	
2	8	After 3 week	48	50
2	8	After 4 week	64	

Source Survey study, 2023

Status of pump on market

From respondents response, high availability of pump on the market, vulnerable to damage and access to sufficient spare part were Kama, its value were 60.66%, 64.45 and 44.08 respectively Table 13. Moreover, the lowest were Cushion having 1.42%, 3.32% and 3.78% respectively.

Table 13

Table 13 Pump Type

Pump type	Availability on market in %	Consumption of fuel in %	More vulnerable to damage in %	Sufficient spare parts in %
Honda	8.53	5.21	4.27	10.9
Eagle	5.69	10.9	3.79	12.32
Cushion	1.42	8.06	3.32	3.79
Robin	23.7	60.66	24.64	27.96
Kama	60.66	15.17	64.45	44.08
Bond	-	-	-	0.95

Source Survey study, 2023

Correlation effect of pump damage and cause

The pump damage was negatively correlated with pump maintenance checklist, educational level of HH and experience in irrigation farming. However, positive correlation with age of pump, suction and delivery head. This show as pump maintenance checklist, Educational level of HH and Experience in irrigation farming increase pump damage decreased and vise vase. As age, suction and delivery head increase damage of pump also increase and vise vase Table 14.

Table 14

Table 14 Correlation Effect of Pump Damage and Cause

Variable		Age of pump	Pump maintenance checklist	Maintain pump in live time	Suction depth	Size pump used	Educational level of HH	Experience in irrigation farming
Vulnerable to damage	Corr.	0.61	-.51**	-.117	0.138	.159*	-.623	-.59
	Sig.	0.994	.000	0.107	0.238	0.028	0.091	0.74

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Source Survey study, 2023

Pump maintaining body and expense of maintenance

Only 4.27% from Koro Nagawo responds there was government organization to maintain the pump but the 95.88% states as no any organization on work or support on this. If there is pump failure, they took to Private Garage and traditional pump maintenance garage. Farmers face the cost incurred for maintenance that about (68.25 and 26.07) % responds as very expensive and expensive respectively Table 15.

Table 15

Table 15 Cost of Maintenance

Variable		Respondent's kebele						Total
		Awash	Koro Dagaga	Koka Nagawo	Ejersa koro	bekela Girisa	Wolda Qellina	
Any organization that maintain pump	Yes	0	4.27	0	0	0	0	4.27
	No	28.91	11.85	14.22	9.48	15.64	15.64	95.73
If no, where did maintain pump	Private Garage	19.91	10.43	11.85	7.58	9.48	15.64	74.88
	Traditional pump maintainer	9	1.42	2.37	1.9	1.42	0	16.11
Cost incurred for maintenance for last two years.	Normal	0	1.9	0	0	0	0	1.9
	Medium	1.42	0.95	0	0	0	0	2.37
	Expensive	3.32	5.21	2.37	0.47	7.58	7.11	26.07
	Very Expensive	24.17	6.64	11.85	9	8.06	8.53	68.25

Source Survey study, 2023

Farmers support need from government and NGO

To upgrade of irrigation scheme gap the famers gives Training technicians (Engineering work shop technician and IMX) as first rank (30.80%), provision of standard material and equipment (pump) as second (27%), organizing farmers Training water users committee on pump as third Table 16.

Table 16

Table 16 Farmer Need of Supports

Variables	Frequency	Percent (%)
Training technicians (Engineering work shop technician and IMX)	65	30.8
Provision of standard Material & equipment (pump)	57	27
Organizing farmers and Training water users committee on pump	37	17.5
Availing manuals and guidelines	8	3.8
Financial support for overhead costs	9	4.30

Source Survey study, 2023

Constraints in utilization of small Holder irrigation pump

Lack of spare parts, price of spare parts and easiness of the pump for maintenance were the three constraint take rank from one to three as respondent responds

Table 17

Table 17 Constraint/Problem of Pump

Rank	Constraints
1st	Lack of spare parts
2nd	High price of spare parts
3rd	Maintenance difficulty
4th	High price of pump
5th	Difficulty operates of pump
6th	Un availability of credit services
7th	Un durability of the pump
8th	Difficult portability of the pump
9th	Un willingness to use pump together
10th	Un availability of pump

Source Survey study, 2023

4. CONCLUSION

This study was conducted among potential irrigation pump users in Doddota, Arsi, Dugda, and Bora woreda in the East Shewa zone. The respondents identified pump damage, pump cost, long priming time, and fuel consumption as the biggest challenges in pump irrigation schemes. Pump damage was found to be positively correlated with the use of un-recommended suction and delivery head, pump age, long priming time, and continuous operation time. However, it was negatively correlated with pump maintenance, experience in irrigation farming, and educational level of the household. Long priming time and fuel consumption were also found to be positively correlated with the use of un-recommended suction and delivery head, pump age, operation time, and pump size. Among the different types of pumps, KAMA pumps were reported to have the highest availability on the market but were also vulnerable to damage. Spare parts for KAMA pumps were reported to be sufficient, with a value of 60.66%, 64.45%, and 44.08% respectively. The lowest availability was reported for Cushion pumps, with values of 1.42%, 3.32%, and 3.78% respectively. Respondents also reported that due to the absence of a governmental pump maintenance organization, the cost of maintenance at local and private garages was very expensive (68.25%) and expensive (26.07%) respectively. This poses another problem for small-scale irrigation pump users.

The farmers need supports from GO & NGO to training on pump, provision of standard Material & equipment (pump), organizing farmers, financial support and credit facility for purchase. Therefore, it is recommended to GO to add pump maintaining structure at engineering center which serves' closely to scheme users and providing regular training on maintenance checklist. It is also recommended for engineering and socio economic researchers to conduct research collaboratively to assess the gap frequently for other kebele pump user and technical performance evaluation for pump that have problems.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

REFERENCES

Bowley, A. L. (1925). Measurement of the Precision Attained in Sampling.

Effa, K., Fana, D. M., Nigussie, M., Geleti, D., Abebe, N., Dechassa, N., ... & Berisso, F. E. (2023). The Irrigated Wheat Initiative of Ethiopia: a New Paradigm Emulating Asia's Green Revolution in Africa. Environment, Development and Sustainability, 1-26. https://doi.org/10.1007/s10668-023-03961-z

Kamwamba-Mtethiwa, J., Weatherhead, K., & Knox, J. (2016). Assessing Performance of Small-Scale Pumped Irrigation Systems in Sub-Saharan Africa: Evidence from a Systematic Review. Irrigation and Drainage, 65(3), 308-318. https://doi.org/10.1002/ird.1950

Mohammed, M., & Shallo, L. (2020). Impact of Adopting Motor Pump Technology on Smallholder Farmers' Income: Empirical Evidence from Southern Ethiopia. Am. J. Econ, 10, 241-256.

Morris, M., Lynne, V., & Energy, N. C. A. T. (2006). Maintaining Irrigation Pumps, Motors, and Engines.

Mume, I. D., Mohammed, J. H., & Ogeto, M. A. (2023). Impact of Small-Scale Irrigation on the Livelihood and Resilience of Smallholder Farmers Against Climate Change Stresses: Evidence from Kersa District, Eastern Oromia, Ethiopia. Heliyon, 9(8). https://doi.org/10.1016/j.heliyon.2023.e18976

Nakawuka, P., Langan, S., Schmitter, P., & Barron, J. (2018). A Review of Trends, Constraints and Opportunities of Smallholder Irrigation in East Africa. Global food security, 17, 196-212. https://doi.org/10.1016/j.gfs.2017.10.003

Teha, D., & Jianjun, L. (2021). Factors Affecting Adoption of Small Scale Irrigation Technology: Insights from Sire Woreda, Oromiya Region, Ethiopia. American Journal of Applied Scientific Research, 7(4), 84-101. https://doi.org/10.11648/j.ajasr.20210704.12

Tesfaye, M. Z., Balana, B. B., & Bizimana, J. C. (2021). Assessment of Smallholder Farmers' Demand for and Adoption Constraints to Small-Scale Irrigation Technologies: Evidence from Ethiopia. Agricultural Water Management, 250, 106855. https://doi.org/10.1016/j.agwat.2021.106855