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Factors influencing the Utilization of Hand-Dug Shallow Wells for Agricultural and Domestic Water Supply in Harawa District, Somali Region, Ethiopia

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ABSTRACT

Among various possible options to address water scarcity problems in the Somali region, the use of hand-dug shallow Wells for extracting groundwater holds considerable importance. Nevertheless, its actual utilization has not met expectations. This study aimed to assess determinants for the use of hand-dug wells as a source of irrigation and domestic water consumption in the Harawa district. Mixed (quantitative and qualitative) approach was used for the data collection. Descriptive statistics and Binary Logistic regression model were applied for the analysis. From the fourteen explanatory variables fitted in binary logistic model, education status, average distance to water sources, labor availability, training, and farming experience showed statistically positive significance ($p < 0.05$) effect on the agro-pastoralists' decision to use hand dug shallow, where, the age and livestock ownership variables were found to have a significant ($p < 0.05$) negative relationship with the utilizations of the HDSWs. In conclusion, targeted interventions addressing these key factors could substantially promote the utilization status of HDSWs, thereby increasing water access and supporting sustainable livelihoods in agro-pastoral communities

INTRODUCTION

Globally, access to reliable water sources is a critical issue for ensuring domestic water security and improving agricultural productivity. Recent estimates indicate that nearly two-thirds of the world's population experiences severe water scarcity during at least part of the year (Mekonnen & Hoekstra, 2016). Climate change and variability further intensify this challenge by negatively impacting both water availability and crop yields (Li *et al.*, 2022). According to the United Nations (2023), over two billion people still lack access to safely managed drinking water. Furthermore, approximately 1.2 billion individuals reside in agriculturally dependent regions facing chronic water stress or recurrent droughts, undermining the resilience of rainfed farming and pastoral systems (FAO, 2020). Groundwater remains an indispensable water resource, supplying over 40% of the world's irrigated land and more than half of global drinking water demand (FAO, 2022). In semi-arid regions, hand-dug shallow wells (HDSWs) represent a vital water source used to extract groundwater due to their affordability and ease of construction. However, their effective utilization is often limited by a combination of environmental, technical, socio-economic, and institutional constraints (UNESCO, 2023).

In Sub-Saharan Africa (SSA), the situation of limited access to water becomes particularly dire, as a large proportion of the population, approximately more than 80% live in rural areas and rely primarily on rainfed agriculture and livestock for their livelihood (FAO, 2020; UNECA, 2021). This heavy dependence on climate-sensitive sectors renders the region particularly vulnerable to climate change-induced rainfall variability, thereby

increasing the risk of food and water insecurity (Berhanu & Beyene, 2014; Burney & Naylor, 2012; FAO, 2005; Worqlul *et al.*, 2019). Additionally, over 400 million people in SSA do not have access to basic drinking water services, and many communities experience declining water quality and seasonal shortages (WHO & UNICEF, 2021). Water scarcity affects not only household consumption but also livestock productivity, which is vital for agro-pastoralist communities, leading to increased migration, conflict over resources, and economic losses (Hope *et al.*, 2020). Hand-dug wells offer an accessible solution.

Ethiopia is a prime example of these challenges. Despite having abundant water resources, the country faces chronic water access issues, particularly in rural and drought-prone areas. Its agricultural sector, which is primarily rain-fed and small-scale, often fails to meet national food demands due to irregular rainfall and climate variability factors (Adugna, 2014; Zerssa *et al.*, 2021). The Somali Regional State is one of the most vulnerable regions, with pastoral and agro-pastoral people relying significantly on seasonal water availability for both agricultural and domestic requirements. The region is characterized by low and unreliable rainfall, frequent droughts, and fragile ecosystems, which compound the risk of water insecurity. One promising strategy to address water shortages, especially during dry seasons and critical crop growth stages, is the use of shallow groundwater through HDWs (Prastowo *et al.*, 2007). This approach has the potential to boost rural livelihoods by contributing to improved food security and ensuring access to household water. The technology is recognized for its simplicity, affordability, and adaptability, requiring only basic technical skills to manage and maintain (Kariuki, 2004; Ngigi, 2003).

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However, its utilization remains inconsistent and differs significantly across various communities and contexts. Several studies have explored the factors affecting the use of HDSWs, with a main focus on biophysical and technical aspects that impact their sustainability. Environmental factors such as fluctuating groundwater levels, unstable soils, and contamination from surface runoff have been revealed to influence well usability and sustainability (MacDonald *et al.*, 2020). Technical determinants, including insufficient depth, poor structural design, and lack of protective features, often compromise the effectiveness and safety of wells, particularly during dry seasons (Ibrahim *et al.*, 2021). In contrast, socio-economic and institutional factors have received comparatively limited attention, despite their important role in determining the adoption and long-term use of HDSWs. Research by Eberhard and Ghebremichael (2022) highlighted that income levels, availability of labour, gender roles, and local knowledge substantially affect the construction and sustainability of wells. They also recognized institutional aspects such as weak policy frameworks, lack of training, ambiguous land and water rights, and limited community organization as barriers to effective utilization of the HDSWs. Overall, although environmental and technical factors have been widely studied, there remains a critical need to investigate the socio-economic and institutional dimensions of HDSW utilization, particularly in agro-pastoral regions where these wells could enhance water access and livelihood resilience.

In Harawa District, located in the western part of the Somali Region, HDSWs are vital for both domestic water supply and small-scale agriculture. However, their utilization remains lower than anticipated, despite their apparent benefits. The reasons behind this variation in use are not yet fully understood. Some households consistently use and maintain their wells, while others abandon or ignore them. Understanding the determinants of this disparity is crucial for informing future interventions. Therefore, this study aims to explore the socio-economic and institutional factors that influence the utilization of hand-dug wells in Harawa District, with a view to promoting more effective and equitable use of groundwater resources for domestic and agricultural needs.

MATERIALS AND METHODS

Description of the study area

This study was conducted in Harawa District of the Somali National Regional State (SNRS), Ethiopia. The district is located in the northeastern corner of the region, bordering northern Somalia, and lies at approximately 10°00' N latitude and 43°20' E longitude. It is situated about 64 km northwest of Jigjiga, the capital city of SNRS. Harawa is bordered by the Siti Zone to the northwest, Awbarre District to the south and southeast (within the Fafan Zone), and Somalia to the north and east. The district is characterized by a lowland topography consisting of flat to gently sloping terrain, scattered hills, and dry valleys, with elevations ranging from 500 to 1100 meters above sea level.

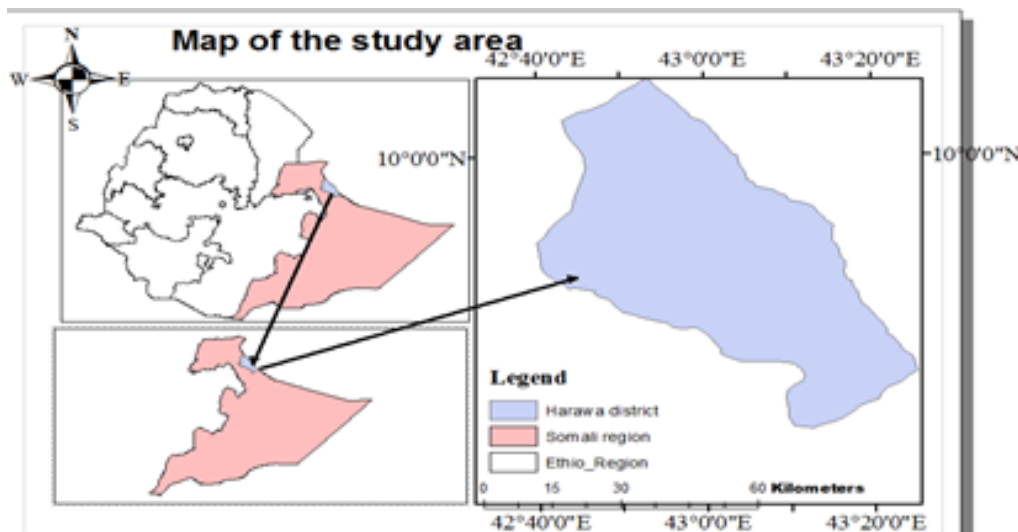


Figure 1: Location of the study area

The climate is arid to semi-arid, with a bimodal rainfall pattern Gu'u rains (from late March to mid-May) and Karan rains (from July to early September). Average monthly minimum temperatures range from 7°C in August to 13.4°C in March, while maximum temperatures range from 27.2°C in July to 30.3°C in March. Annual potential evapotranspiration is around 1750 mm, limiting the rain-fed growing season to less

than 50 days (National Meteorological Services Agency [NMSA], 2000). Geologically, the district is dominated by limestone and basalt rock formations (Purcell *et al.*, 2011), with major soils including deep vertisols and fluvisols formed from alluvial deposits. These soils fall under the xerosol category, typical of arid and semi-arid zones (Ethiopian Mapping Authority [EMA], 2000). The vegetation is dominated by xerophytic thorny shrubs,

grasses, and other drought- and salt-tolerant species, including low acacias (Oromia Water Works and Design Enterprise [OWWDE], 2012). The drainage system is primarily composed of temporary streams and dry riverbeds fed by rainfall in nearby highlands, with the Harawa River serving as the main watercourse. However, water resources are scarce and rainfall is highly erratic. Over the past decade, environmental degradation has worsened, leading to reduced water quality and increased evapotranspiration (Kassahun *et al.*, 2008). Traditional water storage methods such as cisterns and plastic-lined ponds are commonly used, while groundwater extraction through HDSWs drilled wells is becoming progressively widespread.

The total population of Harawa District is 74,580, with 58% male and 42% female. About 85% of the population lives in rural areas, primarily depending on crop and livestock production for their livelihoods, while the remaining 15% reside in urban and peri-urban areas (Central Statistical Agency [CSA], 2018). Most residents are agropastoralists, engaging in both crop cultivation and livestock rearing. The district has a livestock population of 290,714, including sheep (44.9%), goats (38.1%), cattle (11.2%), camels (3.5%), and donkeys (2.5%). Commonly grown crops include sorghum, maize, tomatoes, cabbage, green peppers, watermelon, and oranges. In addition to agriculture, residents generate income through petty trade, remittances, and daily wage labor.

Research Design

To achieve the objectives of this study, a mixed-methods research design was employed, integrating both qualitative and quantitative approaches. Qualitative data were gathered through Focus Group Discussions (FGDs),

Key Informant Interviews (KIIs), and systematic field observations, offering rich, contextual, and experiential insights. In parallel, substantial quantitative data were collected through structured household interviews, facilitating statistical analysis and enabling comparisons across different household groups. This integrated approach allowed for a comprehensive understanding of the research problem by combining the depth of qualitative findings with the generalizability and analytical strength of quantitative data.

Sampling technique and size determination.

A stratified random sampling technique was used to ensure representative household sampling. First, two kebeles (least administrative unit in Ethiopia) Armo and Dhamal were randomly selected from a total of 15 kebeles in Harawa district. Given the topographic differences among household farms, which could influence aquifer discharge and HDSW utilization, the selected kebeles were further categorized into upper and lower dwellers based on their location. Within each category, agropastoralist households were stratified into users and non-users of HDSW to facilitate comparative analysis. Using proportional random sampling, 70 households were selected from each stratum, resulting in a total of 140 households surveyed out of the 1,341 households in the selected kebeles. The sample size was determined using the simplified formula proposed by Yemane (1967), with a 95% confidence level, a degree of variability of 0.5, and a precision level (*e*) of 8%, as cited in Israel and Glenn (1992):

$$n = N / (1 + N(e)^2) = 1341 / (1 + 1341(0.08)^2) \dots(1)$$

Where *n* is the required sample size, *N* is the total number of households, and *e* is the level of precision.

Table 1: Summary of surveyed household sample

Selected Kebeles	Household topographic location	Agro-pastoralist households			
		Total households		Sampled household	
		Users	Non-users	Users	Non-users
Armo	Upper	161	165	17	17
	Lower	128	144	14	15
Dhamal	Upper	165	193	18	20
	Lower	204	181	22	19
	Total	658	683	70	70

Data Sources and method of collection

Both primary and secondary data were collected for this study. Primary data collection involved, direct observations, household surveys, interviews, questionnaires, checklists, and focus group discussions with household heads and key informants, including elders, knowledgeable individuals, NGO representatives, Kebele and district administrators, and natural resource experts. Observational data provided insight into the physical and socio-economic conditions of the study area, including soil type, vegetation, slope, proximity to streams and rivers, water sources, and socio-economic

activities of the local community.

Household surveys, guided by semi-structured questionnaires, gathered general information about selected households and explored determinant factors related to the use of HDSW. Focus group discussions were conducted with stratified groups of 6-8 individuals from each Kebele, under close supervision, to collect additional perspectives on HDSW. Key informant interviews were held with twelve individuals from the two Kebeles, comprising village administrators, traditional leaders, agricultural development agents, and rural water supply technicians as well as two district-level experts,

one in rural development and agricultural extension and another in water resources and irrigation. Secondary data were obtained from published literature, meteorological stations, and reports and records from government and non-government organizations relevant to the study area.

Data analysis

The quantitative data collected through the household survey (questionnaire) were organized and analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics mainly frequency, percentage was used for the analysis of demographic characteristics of the respondents. A binary logistic regression model was employed to analyze the determinant factors influencing agropastoralists’ decisions to utilize HDSWs for irrigation and domestic consumptions. The qualitative data were interpreted using concise descriptive statements.

Binary logistic regression model

Various statistical models can be employed to examine the relationship between explanatory variables and technology utilization. In utilization studies where responses are binary—such as whether agro-pastoralists use a particular technology (yes/no) a Binary Logistic Regression Model (BLM) is appropriate (Green, 1991). As noted by Hosmer and Lemeshow (1989), the logistic distribution is particularly well-suited for analysing dichotomous outcome variables due to its mathematical flexibility, ease of interpretation, and fewer underlying assumptions. Accordingly, the BLM was selected for this study to analyze factors influencing the utilization of HDSW.

Following Hosmer and Lemeshow (1989), the logistic function used is

$$P(Y) = 1/1+e^{-(b_0+b_1x_1)} \dots(2)$$

Where,

- P(Y) is the probability of adopting HDWT
- e is the base of the natural logarithm
- b₀ is the intercept
- b₁ is the coefficient of the predictor variable
- X₁ is the explanatory variable

To identify the most influential factors, econometric analysis was conducted using the BLM. A total of fourteen explanatory variables were hypothesized based on relevant literature and the researcher's contextual knowledge of the study area. These included eight continuous variables (age, education level, average distance to water sources, livestock size, distance to market, labour availability, cultivated land size, and farming experience) and six dummy variables (gender, engagement in non-farm activities, access to extension services, access to credit, land ownership, and participation in training). All variables were included in the model to assess their impact on the decision to use or not use HDSWs.

RESULTS AND DISCUSIONS

Demographic characteristics of the respondents

The demographic profile of the 140 sampled agropastoralist households included gender, age, and marital status (Table 2). Of these, 116 households (82.9%) were male-headed, while only 24 (17.1%) were female-headed, indicating a predominance of male leadership among respondents (Table 2). In terms of age distribution, 23.6% were between 18–35 years, 40% between 36–45, and 27.9% between 46-65. A small proportion, 2.1%, were below 18 years, and 6.4% were above 65. This suggests that the majority of respondents were within the economically productive age range of 18-64 years, typically associated with active participation in labour-intensive farming (Mandara, 1998). Those below 18 are generally school-aged or too young for such activities, while those over 64 are often less active due to age-related limitations. Marital status data showed that 70.7% of respondents were married, 12.9% widowed, and 16.4% single (Table 2). A higher proportion of married households implies better access to family labor, which may facilitate the adoption of innovations like HDSWs. In terms of education, a significant majority (67.9%) of respondents were illiterate, with only 10.7% each having completed primary or secondary education, 9.3% reaching preparatory level, and just 1.4% attaining university-level education (Table 2). Limited literacy among most households may reduce their ability to access and understand information about innovative technologies, particularly written materials such as brochures and manuals. Family size also varied: 52.1% of households had between 5 and 10 members, 32.1% had fewer than 5, and only 15.7% had more than 10. While larger families may strain household resources, they also provide more labour for agricultural tasks (Mhinte, 2000). As a result, households with more members may be more likely to use HDSWs to increase productivity and meet family needs.

Table 2: Demographic conditions of the sampled respondents

Variables	Frequency	Percent
1. Gender		
Male	116	82.9
Female	24	17.1
Total	140	100
2. Age		
Below 18	3	2.1
18-35	33	23.6
36-45	56	40
46-65	39	27.9
Above 65	9	6.4
Total	140	100
3. Marital Status		
Married	99	70.7

Single	23	16.4
Widowed	18	12.9
Total	140	100
4. Education		
Illiterate	95	67.9
Primary	15	10.7
Secondary	15	10.7
Preparatory	13	9.3
University	2	1.4
Total	140	100
5. Household size		
Below 5	45	32.1
5 to 10	73	52.1
Above 10	22	15.7
Total	140	100

Econometric analysis of factors affecting utilization of HDSWs

BLM was used to analyze factors affecting agro-pastoralist decision to utilize of HDSW. This model was preferred for the fact that it results can lead to a meaningful interpretation. Moreover, it is mathematically flexible and has easily usable distribution. In addition, it requires fewer assumptions (Hosmer & Lemeshow, 1989). Fourteen explanatory variables were hypothesized that they could have an influence on agro-pastoralists' decision to be user or non-user of HDSWs. The hypothesis was based on information from the related literature, and the researcher's personal knowledge regarding the study area. The hypothesized explanatory variables consisted of eight continuous and six dummy variables, which were as a result fitted in the BLM.

Before the actual implementation of the above model,

logistic regression diagnostics of the model was also considered. Here multi-collinearity and model fitness for the determination of factors affecting utilization of the wells was checked. Prior to multi-collinearity, both the continuous and discrete explanatory variables were checked for the existence of association problem using Variance Inflation Factor (VIF) and contingency coefficients respectively.

Table 3: Variance inflation factors for continuous variables

Explanatory variables	Collinearity Statistics	VIF
Tolerance	VIF	
Age in years	0.754	1.326
Education in years	0.873	1.146
labor availability in adult equivalent unit	0.818	1.222
farming experience in years	0.709	1.410
Total Livestock Unit (TLU)	0.568	1.762
Farm size in ha	0.730	1.371
distance to market in km	0.915	1.093
Average distance to sources of distance in km	0.846	1.182

As a general rule, if the VIF of a variable exceeds 10, there is multi-collinearity. According to Gujarati (2003), to avoid serious problems of multi-collinearity, it is quite essential to omit the variable with value 10 and more from the BLM analysis. As shown in table 3, the values of VIF for all the estimated continuous explanatory variables are small (VIF value < 10), demonstrating that there is no multi-collinearity problem. As a result, all continuous explanatory variables were kept and fitted in to the BLM analysis.

Table 4: Regression results of parameter estimation

Explanatory variables	B	S.E.	Wald	Sig.	Exp(B)
Age of the household head in years	-0.059	.029	4.343	.037*	.942
Education in years	0.260	.079	10.941	.001**	1.297
Sex (1=male, 0= female)	-2.030	1.381	2.160	.142	0.131
Non-farm activities (1=YES,0=NO)	-1.279	.684	3.495	.062	0.278
Access to credit (1=YES,0=NO)	0.290	.704	.170	.680	1.337
Land ownership (1=YES,0=NO)	0.470	.870	.292	.589	1.600
Market distance in km	0.002	.047	.002	.965	1.002
Labor availability in adult equivalent ratio	0.149	.039	5.068	.001***	1.196
Farm size in ha	0.016	.793	.000	.984	1.016
Distance to water source in km	0.564	.264	4.571	.033*	0.569
Extension contacts (1=YES,0=NO)	-0.032	.649	.002	.960	0.968
Training (1=YES,0=NO)	0.057	.224	6.183	.013*	0.573
Livestock size in TLU	-0.060	.024	6.386	.001*	0.942
Farming experience in years	0.083	.042	3.879	.049*	1.087
Constant	2.980	2.129	1.958	.162	19.679

-2 Log likelihood	= 83.004				
pseudo R2	= 0.730				
Ch-square	= 4.273				
Sensitivity	= 87.1%				
Specificity	= 86%				
Number of cases	=140				

** Significant at 5%, and * significant at 10% significance level.

Model fitness

As shown in table 4, the value of pseudo R2 is 0.730, which is greater than 0.2. From this it can be deduced that the fourteen estimated explanatory variables explained the utilization of HDSW by 73%, therefore the model is fit to apply. Similarly, the -2 Log likelihood and the tabulated chi-square were estimated and found to be 83.004 and 4.273, respectively and they showed small values (Table 4). These statistics (-2 Log likelihood and chi-square) measure how poorly the model predicts the decisions, thus the smaller the statistic the better the model. In addition, the sensitivity (correctly predicted HDSWT users) and the specificity (correctly predicted HDSW non-users) were tested and found to be 87.1% and 86%, respectively. Therefore, the model predicted both groups accurately (Table 4).

Discussion on significant explanatory variables

The results of this study align with prior expectations, confirming that the decision to utilize or not utilize HDSW was influenced by multiple factors. Binary Logistic Model (BLM) analysis showed that out of fourteen hypothesized explanatory variables, seven had a statistically significant effect (positive or negative) on the utilization of HDSW at the 10% significance level (Table 4). Education level, average distance to water sources, labour availability, training, and farming experience exhibited a positive relationship with HDSW utilization, suggesting that increases in these variables enhance the likelihood of utilizing the technology. In contrast, age and livestock size were negatively associated with HDSW utilization, indicating that increases in these factors reduce the probability of adoption.

Age: Age was found to have a negative and significant relationship with HDSW utilization at the 10% level. Older household heads were less likely to adopt the technology, with the odds ratio indicating a 94.2% decrease in utilization likelihood as age increased, holding other factors constant. This is consistent with the findings of Fitsum *et al.* (2019) in Wondo Genet, Ethiopia. However, Mume and Kamal (2014) observed a positive correlation between age and rainwater harvesting adoption in Eastern Hararghe, Ethiopia, indicating that the relationship may vary depending on the technology and context.

Education: Education had a positive and significant effect at the 5% level. Households with higher education levels were more likely to utilize HDSW, likely due to better access to information and understanding of the

technology's benefits. Educated agro-pastoralists were also more capable of assessing market potential and handling technical aspects of the technology. Similar conclusions were reached in studies by Baramo (2023), Deressa *et al.* (2009) and Nhemachena and Hassan (2007). **Labor Availability:** Labor availability had a strong positive impact at the 1% significance level. A one-unit increase in adult-equivalent labour increased the likelihood of using HDSW by a factor of 1.196, reflecting the labour-intensive nature of the technology for both construction and ongoing farm maintenance. This finding aligns with previous studies by Jemal (2014) and Million and Belay (2004)

Distance to Water Sources: The average distance to water sources was positively associated with HDSW utilization at the 10% level, although the relationship was relatively weak. A one-unit increase in distance increased the likelihood of adoption by 57%, assuming other factors remain constant. Field observations indicated that users of HDSW were often situated closer to their water sources and depended more heavily on them, unlike non-users who had access to multiple public water sources. This result contrasts with Misgana (2015), who reported a negative relationship between water source distance and water harvesting scheme use in Sebeta Hawas District.

Training: Participation in training programs significantly increased the probability of HDSW utilization at the 10% level. A one-unit increase in training was associated with a 0.573 increase in the odds of using the technology. Training improved agro-pastoralists' technical and operational understanding of HDSW, enhancing their confidence and ability to maintain the system. Similar findings were reported by Abadi (2006) and Kumar *et al.* (2016).

Livestock Size (TLU): Livestock size, measured in Tropical Livestock Units (TLU), had a negative and significant relationship with HDSW utilization. A one-unit increase in TLU reduced the probability of adoption by 94.2%. Focus group discussions and key informant interviews suggested that households with more livestock prioritized animal husbandry over crop production and had less available labour for irrigation-related tasks. This inverse relationship aligns with Asret and Anteneh (2019) but contradicts findings by Cathryn and Charlotte (2000), Geoffrey (2004), and Molla (2005), who reported a positive correlation between TLU and technology adoption.

Farming Experience: Farming experience showed a positive and significant effect on HDSW utilization at the

10% level. Each additional year of farming experience increased the likelihood of using HDSW by a factor of 1.087, assuming other factors remained constant. Households with longer histories of crop production were more likely to seek out and adopt irrigation technologies as a means of improving productivity. This finding is supported by Aziz and Tesfaye (2013), Melaku and Molla (2005), Molla (2005), and Tesfaye (2006).

CONCLUSION

The findings of the study exposed that education level, labour availability, training, farming experience, and proximity to water sources had a positive and significant relationship with the utilization of HDSWs, indicating that improvements in these areas could enhance the utilization rates. In Contrary, age and livestock size were negatively associated with the HDSW utilization, declaring that increase in these variables may reduce the likelihood of utilization. Overall, the study concludes that promoting HDSW in the area requires strengthening the enabling factors to ensure improved water access and sustainable livelihoods of the agropastoral community.

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