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Determinants of the Adoption of Charco Dam Rainwater Harvesting Technology by Pastoralists in Semi-Arid Areas of Monduli District in Tanzania

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Abstract

The use of water harvesting ponds in Tanzania known as charco dams in watering livestock have been developed to enhance livestock production in semi-arid areas. However, the adoption of charco dam has been very low. This paper examined the determinants of the adoption of charco dam by pastoralists in semi-arid areas of Monduli District in Tanzania. The study used a cross-sectional research design where data were collected at a single point in time. Quantitative data were collected by using pre-tested structured questionnaire from 367 respondents who were randomly selected from seven villages, namely Moita Kipok, Moita Kilorit, Kilimatinde, Moita Bwawani, Makuyuni, Mbuyuni and Naiti in Monduli District. The collected data was entered into SPSS.20 for analysis. Data was analysed using frequency, percentages, and a binary logistic regression model. The study results show that the intervening factors (perceived advantages and disadvantages of charco dam) have a slightly high influence on the adoption of charco dam with predictive power R^2 ranging from 29.5 to 44.5 per cent as compared to independent variables with predictive power R^2 ranging from 27 to 37 per cent at a 5 per cent level of significance. Furthermore, the study results indicate that the independent variables namely socio-economic factors specifically age (p=0.000), household size (p=0.002), off-farm income (p=0.025), livestock keeping experience (0.001), herd size (0.002) and institutional factors including access to extension services (p=0.030) and subsidies (p=0.005) have an influence on the adoption of charco dam. This study recommends policymakers to devote more weight to perceived advantages and disadvantages of charco dam technology while constructing charco dam rainwater harvesting projects in order to influence pastoralists to accept the technology and increase water access for livestock in semi-arid areas.

Keywords: *Charco dam; adoption; livestock; pastoralists; semi-arid areas*

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Introduction

Rainwater harvesting has gained worldwide recognition and approval as a reliable method of water management (Campisano *et al.*, 2017;

Gebreyess and Amare, 2019; Islam, 2023; Singh *et al.,* 2019). It is an ancient water supply practice, with examples dating back to the Neolithic period (Bruins *et al.,* 1986; Angelakis, 2016). Roughly two-thirds of the Sub-Saharan population is involved in agriculture and pastoralism, which can possibly contribute to the expansion of rainwater harvesting technologies to more areas of drylands (Rockström *et al.,* 2010). Rainwater harvesting is especially important in semi-arid areas of Africa (Roba *et al*., 2022; Chiturike *et al.,* 2023), where water shortage creates substantial obstacles to agricultural and livestock activity (Mdemu, 2021; Chepkoecha *et al.,* 2020; Kimaro *et al.,* 2018). Livestock rearing, particularly pastoralism, is a critical livelihood strategy in these locations, and livestock access to water is critical for herd well-being and production. As a result, limited rainwater harvesting technologies such as charco-dams one of the measures that have shown to successfully improve crops and livestock production (Kiggundu *et al.,* 2018; Tamagnone *et al.,* 2020; Timothy *et al.,* 2022).

A charco dam has emerged as an effective remedy to water constraints by harvesting and reusing rainfall for a variety of applications (Khanal *et al.,* 2020; Rao *et al.,* 2010). According to URT (2020), a charco dam refers to small earth dam built in a way, having maximum capacity of 10,000 m^3 and height of the wall not exceeding 5m which tries to reduce evaporation losses by deepening the water reservoirs and minimizing the surface area. Equally important, a charco dam are referred to as manmade ponds (Rural Radio Resource Pack, 2007). A charco dam is made up of three parts: a runoff generating or collection area (rangelands), a conveyance system (up to 2 km of shallow canals), and a storage area (excavated pond) (Kiggundu *et al*., 2018). Furthermore, there is two categories of a charco dam namely those lined with plastic sheet to reduce seepage of the water and those constructed in flat land.

East Africa stands out in the context of Africa as a region with different semi-arid zones and greatly depends on livestock production (Kimaro *et al*., 2018; Kuhenga, 2020). Countries such as Tanzania face substantial challenges in ensuring water availability for pastoralist communities, given the limited rainfall and arid conditions (Kitasho *et al.,* 2020; Ripkey *et al.,* 2021). The application of water harvesting ponds (in Tanzania known as charco dam) has shown promise in addressing water scarcity for livestock (Mfinanga *et al.,* 2023; Timothy *et al.,* 2022). Despite of all efforts invested to promote the use of a charco dam's rainwater harvesting to combat the problem of water shortage for livestock among pastoralists, only 23.4% out of 367 pastoralist households adopted this technology in the Monduli District (Mfinanga *et al.,* 2023). It was reported the low level of adoption was because of inadequate support in terms of provision of plastic lined sheet used in construction of a charco dam by local government authority and World Vision Tanzania.

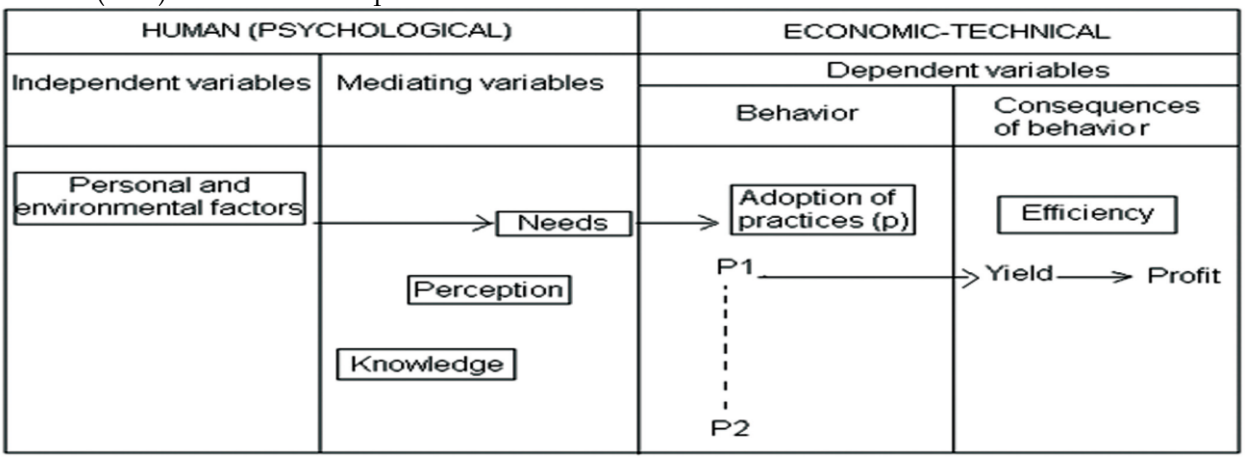
Various factors have been associated with the adoption of agricultural technologies such as charco dam comprising independent factors like socioeconomic characteristics such as age, sex, education, supporting labour, off-farm income, livestock ownership and livestock keeping experience (Dhehibi *et al*., 2018; Mbwambo *et al.,* 2022; Okello *et al.,* 2021) access to a subsidy (Subedi *et al.,* 2020; Saurí and Garcia, 2020). Other independent factors are institutional factors like extension services and access to credit (Ayenew *et al.,* 2020; Lutta *et al.,* 2020); environmental (Chen and Li, 2022; Masi *et al.,* 2022) and intervening factors like needs, perception and knowledge (Msuya, 2021; Khalaf *et al.,* 2020). However, Kurgat *et al.,* (2018) and Mwololo *et al*., (2019) assert that factors influencing the adoption of innovations are location specific. Therefore, this paper examines the determinants of adoption of charco dam rainwater harvesting technology for accessing water for livestock in Monduli District since there is inadequate information on this specific location. Understanding the determinants that influence the adoption of charco dam by pastoralists will enable the policymakers and other stakeholders to address the determinants that negatively affect the adoption and promote the determinants that influence positively the adoption of improved charco dams to enhance water access by pastoralists.

Theoretical Underpinnings

This study is guided by Düvel (1991) model of Adoption Behaviour. According to Düvel (1991), the independent variables such as farmer's characteristics, environmental and institutional factors as well as mediating variables like need, knowledge and perception can influence farmer's adoption behaviour (Figure 1). Furthermore, the model states the influences of independent variables are expressed in adoption behaviour through mediating variables such as needs, perception and knowledge. In the current study mediating variables are also referred to as intervening variables. Moreover, the model was applied to examine only single dependent variable the adoption of a recommended plastic lined sheet charco dam. The model was selected to guide this study because it considers both independent and mediating factors in determining the factors that influence the adoption of technologies in a particular locality (Msuya *et al.,* 2014; Logan and Helen, 2015). Also there is on-going debate of which factors, between independent and mediating (intervening) factors that contribute the most to the adoption behaviour (Msuya, 2021; Afful *et al.,* 2013). Therefore, this study is also expected to fill the knowledge gap.

Figure 1

Düvel's (1991) model of the adoption behaviour

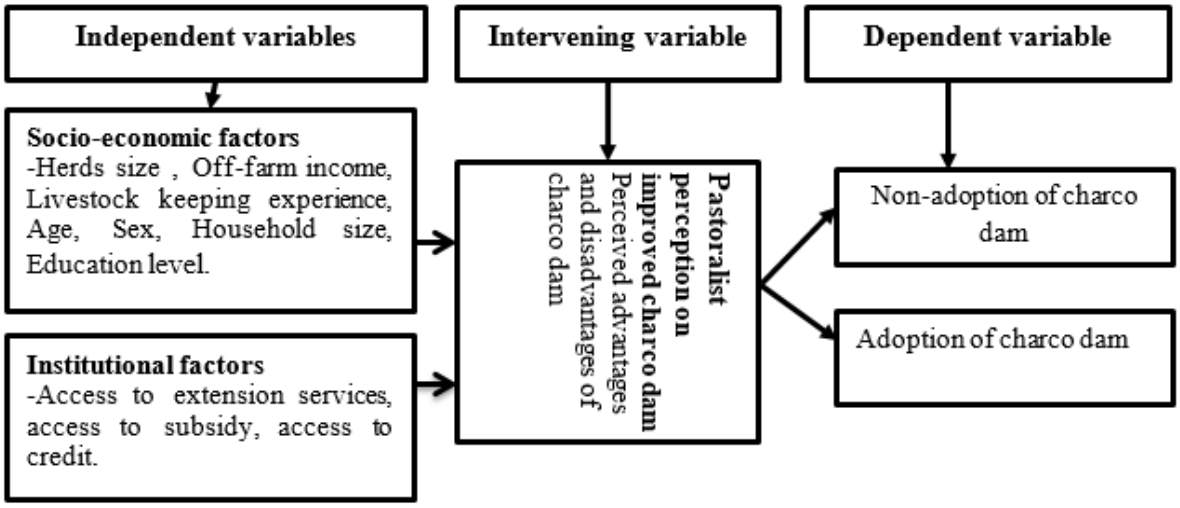


Conceptual framework

Based on the theoretical framework, the conceptual framework for this study was adapted from Düvel (1991) model of Adoption Behaviour. As indicated in Figure 2, the framework has a dependent variable namely the adoption of a plastic lined sheet charco dam. It is assumed that the independent variables namely, personal factors (socio-economic factors) such as individual age, education level, sex and household size and institutional environment factors such as access to extension services, access to subsidy and access to credit under the presence of mediating (intervening) variables namely perceptions (perceived advantages and disadvantages of technology) influence the adoption of a charco dam

Figure 2.

Conceptual framework of the study adapted from Düvel (1991)



Materials and Methods

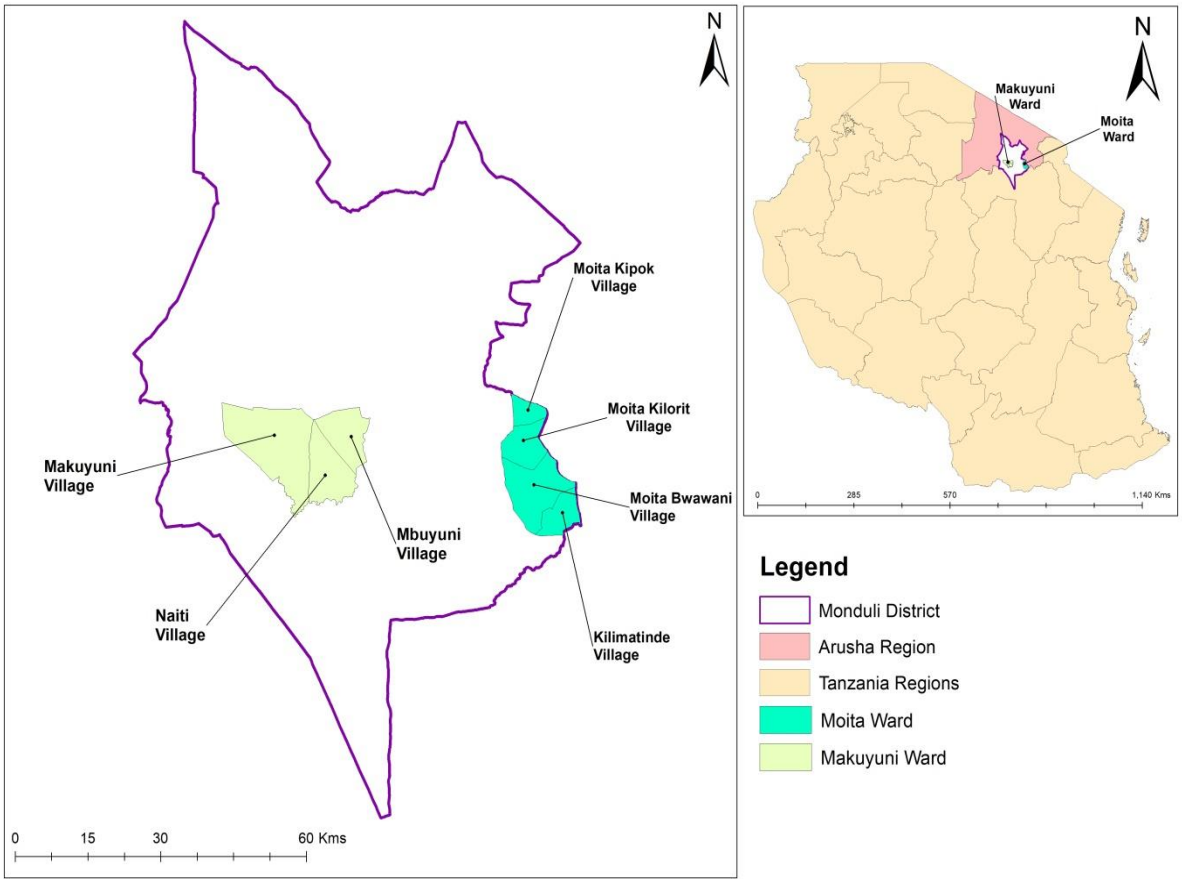
Description of the study area

The study was conducted in Monduli District of the Arusha Region located in Tanzania (Figure 3). The Monduli District is bordered to the East by the Kilimanjaro Region and Arumeru District, to the north by Kenya, to the west by Ngorongoro District and Karatu District, to the South by the Manyara Region. The district has two ecological zones including the highland zone and the low land zone. The highland consists of mountains with rainfall ranging from 500mm to 900mm while the low land consists of arid and semi-arid rangelands with rainfall ranging from 200mm to 600mm (Msoffe *et al.,* 2011). The study area (Figure 3) covers seven villages famous in livestock keeping activities namely, Moita Bwawani, Moita Kapok, Moita Kilorit and Kilimatinde found in Moita Ward and Makuyuni, Mbuyuni and Naiti villages located in Makuyuni Ward. Monduli district was chosen because 97% of individuals are pastoralists and the area experienced water shortage for livestock due to long drought caused by climate change (Theodory and Malipula, 2014). Furthermore, this study focused on adoption of charco dam constructed with lined plastic sheets because soils in the study areas have weak water retention capacity which according to Mbilinyi *et al.,* (2005) asserts that charco dams are best suited to soils with excellent water retention capacity.

Figure 3: A map of Monduli District showing the location of the study areas

Figure 3

A map of Monduli District showing the location of the study areas



Research design, population and sampling procedures

The cross-sectional research design was used, which allows data collection at a single point in time in order to represent a large population (Creswell, 1994). The target population for this study are pastoralists in Monduli district whose livestock keeping account for more than half of their household income (Mohamed, 2019). According to URT (2012) the compositions of the pastoralist's population in seven chosen villages are: Kilimatinde (453), Moita Bwawani (754), Moita Kilorit (533), Moita Kipok (470), Mbuyuni (556), Naiti (465) and Makuyuni (1159). Based on the available numbers of population, a sample size of 367 pastoralist households was computed by using Yamane (1967) formula equation (i).

(i)Yamane formula:

$$n = \frac{N}{1+N\,(e)^2} = \frac{4{,}390}{1+4{,}390(0.05)^2} = 367 \quad \text{.....(i)}$$

Where n =sample size, N is the population size and e is the level of precision (sampling error) =5%.

The sample size of each village was selected proportionally by using Salkind (2010) formula

(ii) Salkind (2010) formula:

$$n_b = \frac{N_h}{N} x\ n$$

..... (ii)

Where: n is the sample size; N is the total population of pastoralist's households, N_h is the population of the village, n_b is the sample of the village. The computed sample sizes for each village are listed as follows: Makuyuni (97), Mbuyuni (46), Naiti (39), Moita Kipok (39), Moita Kilorit (45), Moita Bwawani (63) and Kilimatinde (38). Then the respondents in each village were selected randomly with the aid of lottery sampling technique.

Data collection

Primary quantitative data were collected from pastoralist head of households by using a validated pre-tested structured questionnaire. The collected data were socio-economic characteristics namely herds size, off-farm income, livestock keeping experience, age, sex, household size and education levels. Furthermore, the information's on institutional factors such as access to extension services, access to subsidies and access to credit were collected. Also, information's on perceived advantages and disadvantages of charco dam were collected from head of households. Observations as a method of data collection is "a deliberate, systematic, and purposeful method for watching and paying attention to an event or phenomenon as it occurs" (Kumar, 2005). Throughout the research procedure, this method was applied to determine the location and as well as the use of charco dams for livestock in the investigated villages. The researcher and assistant researchers would frequently hang around near charco dams to watch livestock drinking water and how pastoralists manage them. Initially, leaders of the villages joined the researcher and his assistants to charco dam locations; however, as they became more familiar with the areas, the team was able to walk around on their own, engage in discussions with charco dam adopters, and take photos.

Secondary data were collected through a review of different documents relating to the study such as the Tanzania Water Policy of 2002, National Agriculture Policy of 2013, Tanzania Livestock Master Plan 2017/2018-2021/2022, National Sample Census of Agriculture 2019/2020, Tanzania Livestock Sector Analysis 2016/2017-2031/2032, Water Sector Development Programme phase I and II and National Strategy for Growth and Reduction of Poverty phase I and II. The secondary data collected were Tanzania context of adoption of charco dam rainwater harvesting technology and potential benefits of charco dam adoption among people living in semi-arid areas.

Data analysis

The collected data were entered into Statistical Package for the Social Sciences version 20 for data analysis The study pre-tested the reliability and internal consistency of a questionnaire by using Chronbach's alpha. Pre-testing resulted in a reliability coefficient Cronbach alpha of 0.81 which according to Hair *et al.*, (2010), a questionnaire with a correlation coefficient of Cronbach alpha of 0.70 and above is deemed acceptable and reliable. The quantitative data were coded and entered in the SPSS version 20 for analysis. Each factor was analysed separately by using chi-square and correlation to examine its influence on the adoption of charco dam. Furthermore, the binary logistic regression model (equation iii) was used to assess the influence of all investigated factors on adoption of charco dam.

Before running the model, problem of multi-collinearity was examined through the use of Variance Inflation Factors (VIF).

Equation (iii) binary logistic regression model as specified by Agresti and Finlay (2009):

$$\text{Logit (Pi)} = \log (Pi/1\text{-}Pi) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \quad \text{(iii)}$$

Where:

Logit (Pi) = natural log of an event occurring (dependent variable), which is the probability of a household to adopt charco dam, (1= adopt charco dam, 0 = reject adoption of charco dam).

Pi = probability of (event), this is the likelihood of an event occurring.

1-Pi = probability of (non-event), which is the likelihood of the event not to occur.

B_0 = is the equation's constant.

β_1 to β_k = coefficients of the independent (predictor, response) variables.

k = the number of independent variables.

X_1 to X_k = independent variables entered in the model.

Results

This section discusses the results of independent and intervening factors determining adoption of charco dam water use strategy for livestock in Monduli District. The dependent variable in this study was the adoption of charco dam and other independent factors, are socio-economic and institutional factors. On the other hand, the intervening factors considered are perceived advantages and disadvantages of charco dam. Each independent and intervening factor (variable) is investigated separately by using the binary logistic regression model to assess the influence of all investigated intervening and independent factors on adoption of charco dam.

Binary Logistic Regression Model Results on the influence of independent and intervening factors on adoption of charco dam

The binary logistic regression model was used to analyse the influence of all investigated independent and intervening factors on the adoption of charco dam. Before running the binary logistic regression model analysis, the following diagnostic tests were conducted: Multicollinearity test, which was done to avoid the influence of highly correlated independent and intervening factors in the model; the Pseudo R-squared goodness of fit and Hosmer and Lemeshow tests. The results for independent factors are presented first followed by the results of intervening factors. The study findings show that out of 367 interviewed respondents, 86 (23.4 %) adopted charco dam rainwater harvesting technology while 281 (76.6%) did not adopt.

The influence of independent factors on adoption of charco dam

The results in Table 1 indicate that there is no problem of multicollinearity since Variance Inflation Factor (VIF) to all predictor variables is less than 10 as recommended by Pallant (2011). Also Hosmer-Lemeshow test results show that chi square=3.122, df=10, p=0.415, which according to Canary *et al.,* (2017) a p value of >0.05 is appropriate for Hosmer-Lemeshow test, implying that the fitting effect between the models and the data were good.

According to Table 1 the independent factors entered in the binary logistic regression model are age, sex, formal education, household size, off-farm income, and livestock keeping experience, herd size, access to extension service, access to subsidy and access to credit. The results in Table 1 show that all investigated independent factors except sex of the respondents; formal education and access to credit have significant influence on adoption of charco dam rainwater harvesting technology for livestock water supply. On the other hand, age of the respondents has highly significant influence on adoption of charco dam (p=0.000) followed by other factors like livestock keeping experience (p=0.001), herds size (p=0.002), household size (p=0.002), access to subsidy (p=0.005), off-farm income (p=0.025), and access to extension service (p=0.030).

Moreover, the results of Pseudo R-Squared goodness of fit test conducted in binary logistic regression model on the influence of independent factors (socio-economic and institutional factors) on adoption of charco dam indicate that Cox and Snell R^2 and Nagelkerke R^2 values were 0.27 and 0.377, with the model p value of 0.000 respectively indicate that the model fit the data well since p-value is less than 0.05 significance level (Table 1). This implies that the predictors in the model explain for at least 27% to 37.7% of the influence of independent variables (socio-economic and institutional factors) on adoption of charco dam rainwater harvesting technology for livestock water supply.

Table 1

Binary logistic regression analysis showing the relationship between independent variables and adoption of charco dam

Factor	B	S.E.	Wald	df	Sig.	Exp(B)	VIF
Socio-economic factors							
Age	-0.142	0.019	55.030	1	0.000 *	0.867	4.228
Sex(male reference female)	0.975	1.219	0.640	1	0.424	2.652	1.010

Formal Education(Reference do not)	0.062	0.025	6.191	1	0.513	1.063	1.198
Household size	0.073	0.023	9.716	1	0.002 *	1.075	2.006
Off farm income	1.083	0.960	1.273	1	0.025 *	2.955	1.078
Livestock keeping experience	0.066	0.020	11.044	1	0.001 *	1.068	4.293
Herd size	0.073	0.023	9.716	1	0.002 *	1.075	1.565
Institutional factors							
Access to extension service (Reference do not)	0.853	0.394	4.692	1	0.030 *	2.347	1.499
Access to subsidy (Reference do not)	1.090	0.384	8.070	1	0.005 *	2.974	1.394
Access to credit (Reference do not)	0.081	0.483	0.028	1	0.867	1.084	1.084

Nagelkerke R^2 =0.377; Cox & Snell R^2 = 0.27 Model Chi square=105.565; df=10, p=0.000; Hosmer and Lemeshow Test; chi square=3.122, df=8, p=0.415; * indicates significant at 5%

The influence of intervening variables on adoption of charco dam

The results in Table 2 indicate that there is no problem of multicollinearity since Variance Inflation Factor (VIF) to all predictor variables is less than 10 as recommended by Pallant (2011). Also Hosmer-Lemeshow test results show that chi square=5.325, df=8, p=0.722, which according to Canary *et al.* (2017) a p value of >0.05 is appropriate for Hosmer-Lemeshow test, implying that the fitting effect between the models and the data were good. The intervening variables namely perceived advantages (a charco dam has multiple uses such as fish keeping, watering of livestock and domestic water use , a charco dam simplifies the watering of livestock, a charco dam is manually built, a charco dam reduces the livestock walking distance to reach the drinking water) and the perceived disadvantages namely (a charco dam does not harvest sufficient volumes of water, a charco dam is not reliable source of drinking water for livestock, a charco dam dries up very early and building a charco dam is expensive when one uses equipment such as caterpillar) were entered into binary logistic regression model to determine their influence on the adoption of charco dam. The results in Table 2 show that the influence of various intervening variables as well as their joint contribution to overall variance in adoption explanation. The intervening variables entered in the model contribute significantly ($\chi 2$=128.309, df=8, p=0.000) to the adoption of charco dam. According to Table 2 they explain at least 29.5% to 44.5% of the variation in adoption (Cox & Snell R^2 = 0.295; Nagelkerke R^2 =0.445).

Table 2

Binary regression analysis showing the relationship between intervening variables and adoption of charco dam

Factor	B	S.E.	Wald	df	Sig.	Exp(B)	VIF
Perceived advantages							
Charco dam has multiple uses such as fish keeping, watering of livestock and domestic water use	0.316	0.144	4.779	1	0.029*	1.371	1.351
Charco dam simplifies the watering of livestock	0.088	0.149	0.352	1	0.553	1.092	1.051
Charco dam is manually built	0.723	0.150	23.216	1	0.000*	2.061	1.130
Charco dam reduces the livestock walking distance to reach the drinking water	0.699	0.128	29.646	1	0.000*	2.011	1.019
Perceived disadvantages							

Charco dam does not harvest sufficient volumes of water	-0.261	0.126	4.329	1	0.037*	0.770	1.127
Charco dam is not reliable source of drinking water for livestock	-0.351	0.143	6.064	1	0.014*	0.704	1.354
Charco dam dries up very early	-0.234	0.141	2.753	1	0.097	0.792	1.222
Building a charco dam is expensive when one uses equipment such as caterpillar	-0.134	0.137	0.964	1	0.326	0.875	1.041

Nagelkerke R^2 =0.445; Cox & Snell R^2 = 0.295; Model Chi square=128.309; df=8, p=0.000; Hosmer and Lemeshow Test; chi square=5.325, df=8, p=0.722; * indicates significant at 5%

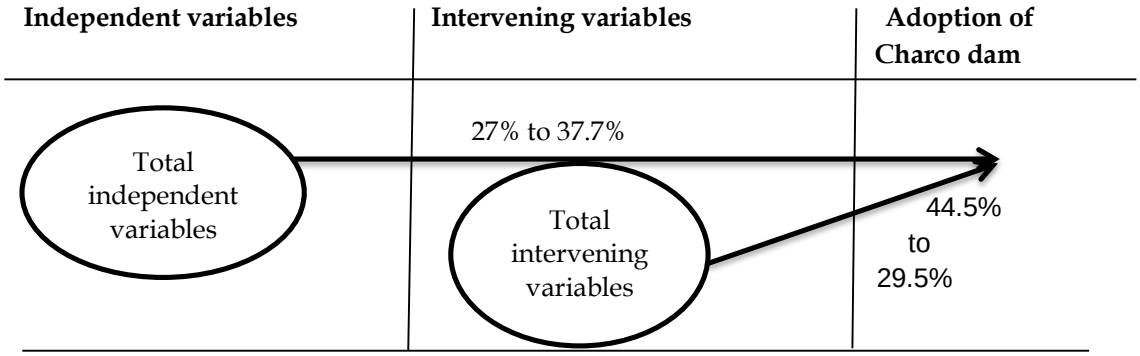
As regards to the intervening variables three perceived advantages including charco dam has multiple uses like fish keeping (aquaculture), watering of livestock, and domestic water use (p=0.029), and reducing livestock walking distance to reach the drinking water (p=0.000) have highly significant influence on the adoption of charco dam. On the other hand, the perceived disadvantages with limiting adoption of charco dam include charco dam failing to harvest sufficient volumes of water (p=0.037) and charco dam being unreliable source of drinking water for livestock (p=0.014).

Comparisons between independent and intervening variables

This section summarizes the comparison of independent and intervening variables with the goal of demonstrating which variables are more powerful in predicting pastoralists' adoption of charco dam. As indicated in Figure 4, the independent variables contribute 27% to 37.7% to explain the variation in adoption of charco dam while the intervening variables contribute 29.5 % to 44.5% to explain the variation in adoption of charco dam. This implies the influence of intervening variables is slightly higher than that of the independent variables in terms of predicting the adoption behaviour.

Figure 4

Comparative contribution of independent and intervening variables on the adoption of Charco dam



Discussion

The adoption of charco dam rainwater harvesting technology by pastoralists in the study area was determined by two groups of factors, namely the independent and intervening variables. The results revealed that the independent variables namely socio-economic and institutional factors were capable of predicting the adoption of charco with the predictive power (R^2) ranging between 29.5 to 44.5 %. Furthermore, Dhehibi *et al.,* (2018) in Tunisia found that the socio-economic factors namely age, household size, off-farm income,

livestock keeping experience and herd size influenced the adoption of water conservation technology. In terms of age in this study youth were more likely to adopt charco dam rainwater harvesting technology as water use strategy for livestock as compared to elders. This implies that youth are ready to take risks to adopt new technology, as compared to elders. The study finding concur with that of Zenebe (2020) which found that youth pastoralists in Ethiopia have a higher chance of adopting rainwater harvesting technology as compared to elders. This is because the construction of charco dam is a labor intensive task that elders are less likely to do.

Furthermore, household size in this study positively significantly (p=0.002 B =0.073); Exp(B)=1.075; at p<0.05) determined the adoption of charco dam rainwater harvesting technology for livestock water supply. This implies that households with large size have a large chance of adopting charco dam rainwater harvesting technology because of excess labour force that provide assurance of labour availability for construction of charco dam as compared to households with small household size. Similarly, Ayenew *et al.,* (2020) posits that household size influences the adoption of agriculture innovation among smallholder farmers in Ethiopia. Additionally, the study revealed that off-farm income significantly (B =1.083); p=0.025; Exp(B)=2.955; at p<0.05) determined the adoption of charco dams. This suggests that pastoralist's households who participated in off-farm income generating activities were more likely to adopt charco dams due to generated excess income than those who practised only livestockkeeping. This study is in line with Mengistu (2021) found that the adoption of rainwater harvesting technology in Ethiopia was significantly influenced by the household head's off-farm income.

Furthermore, the adoption of the charco dam rainwater harvesting technology was considerably and substantially influenced by livestock keeping experience. In the study area's pastoralists have been involved in livestock-related activities since they were young. By doing so, they gained considerable knowledge and information about the need for innovative technologies and strategies to secure water for livestock and their livelihoods. Therefore, household head livestock keeping experiences positively significantly (B =0.066); p=0.001; Exp(B)=1.068) influenced the adoption of charco dam rainwater harvesting technology. This implies the respondents with livestock keeping experiences had a 1.068 times likelihood of adoption of charco dam than those who do not have livestock keeping experience.

Additionally, the herd's size influenced positively significantly (B =0.073); p=0.002; Exp(B)=1.075; at p<0.05) the adoption of charco dam rainwater harvesting technology among pastoralist's household heads in the study area. Pastoralists with large herd's size were more likely to adopt charco dams as compared to those with small herd's size. This is because as the pastoralists increase the herd's size the thrust of securing water access for livestock increases due to high demand of water supply for livestock. Similarly, Dhraief *et al.,* (2018) posits that the herd's size possessed by household significantly influence the adoption of innovative technologies. However, the finding of this study revealed that the independent variables (socio-economic and institutional factors) have slightly less predictive power R^2 ranging between 27% to 37.7% of the adoption of charco dam rainwater harvesting technology as compared to intervening variables with the predictive power R^2 ranging between 29.5 % to 44.5%. This finding is consistent with the earlier studies by Afful *et al.* (2013) and Msuya (2021) in South Africa and Tanzania who found that the intervening variables were more powerful than independent variables in predicting the adoption of innovative technologies among farmers.

The intervening variables significantly determined the adoption of charco dam were the perceived advantages and perceived disadvantages of charco dam rainwater harvesting technology. The traits of the usefulness of charco dams on livestock water supply and livelihoods by pastoralists have a direct linkage to adoption of innovation. According to Laksono *et al.,* (2022) and Msuya (2021) add that individual perceived behaviour on recommended technology/practices has influence on adoption of innovation. The study

found the perceived advantages including charo dam has multiple uses such as fish keeping, watering of livestock to mention a few (B =0.316); p=0.029; Exp(B)=1.371; at p<0.05), charco dam is manually built (B =0.723); p=0.000; Exp(B)=2.061; at p<0.05) and charco dam reduces the livestock's' walking distance to reach the drinking water (B =0.699); p=0.000; Exp(B)=2.011) affect the adoption of charco dam. This implies that the pastoralists that consider charco dam has multiple uses had a 1.371 times likelihood of adopting charco dam as compared to those does not perceive charco dam has multiples uses. In other words, the respondents who had positive perception on perceived benefit of multiple uses of charco dam are more likely to adopt charco dam as compared to those deny the potential benefit of multiple uses of charco dam. Also, the respondents who perceived charco dam is manually built had a 2.061 times likelihood of adopting charco dam than those who do not perceive charco dam can be built manually. Constructing manually charco dam served as incentive for pastoralists to adopt the charco dam because they perceive its within their limit and resources. Moreover, the pastoralists perceived charco dam shortens the distance that livestock need to walk in order to access drinking water had a 2.011 times likelihood of adopting charco dam as compared to those perceive not capable of shorten walking distance to water point by livestock. Therefore, households with charco dam their livestock are likely to walk short distance to water source as compared those without charco dam.

As well as the perceived disadvantages of charco dams (charco dam does not harvest sufficient volumes of water (B =0.066); p=0.001; Exp(B)=1.068) and charco dam is not a reliable source of drinking water for livestock (B =0.066); p=0.001; Exp(B)=1.068) influenced the adoption of charco dam technology for livestock water supply. This implies that pastoralists are willingly to adopt charco dam despites of the uncertainty that charco dam cannot harvest sufficient volume of water. This decision raises serious concerns regarding the factors that influence the adoption of water harvesting technologies, as well as the consequences of adopting technology that may not fully meet the needs of consumers. One possible explanation for respondents' use of the Charco Dam despite their view of its inadequate water harvesting capability is a lack of feasible alternatives. Access to water for livestock is a big issue in many rural semi-arid areas, and people may be forced to employ inadequate technologies simply because better ones are unavailable. Barron (2009) contends that water levels stored in a charco dam are estimated to last 2 to 6 months. Therefore, pastoralists being sure of getting water for their livestock to survive even for a few months is the important thing for them to adopt the technology to save their livestock and support their livelihood. This is contrary to the study by Jha *et al.* (2019) in Tanzania which found that conservation behaviour of rainwater harvesting technologies is hampered when the resource is limited, that there is no water to conserve. However, similar findings reported by Kahsay *et al.,* (2019) in Ethiopia found a positive association between farmer perception of low and erratic rainfall and adoption of water conservation technologies. Furthermore, Massawe et al. (2014) emphasize that both positive and negative features of technology might have an impact on a user's decision to adopt a technology, negative attributes are more powerful.

The results confirm those of earlier studies, which show that intervening variables have a greater influence on adoption of innovation as compared to independent variables (Afful *et al.,* (2013); Msuya *et al.,* 2021). This study demonstrates that pastoralists' perceptions of the advantages and disadvantages of the charco dam rainwater harvesting technology are the most essential factors when deciding whether or not to adopt the charco dam. Furthermore, Massawe *et al.* (2014) emphasize that both positive and negative features of technology might have an impact on a user's decision to adopt a technology, negative attributes are more powerful. Therefore, for adoption of technology to take place the perceived potential benefits and disadvantages of the technology is very important for the adopter's decisions.

Conclusion

Based on the study findings three conclusions can be made. Firstly, the adoption of Charco dam rainwater harvesting technology for livestock

water use among pastoralists is relatively low. Secondly, the perceived advantages and disadvantages of the Charco dam seem to be more important input for the respondents to adopt Charco dam. Thirdly, the determinants of the adoption of Charco dam for livestock water supply are age, livestock-keeping experience, herd size, household sizes, off-farm income, access to extension services and access to subsidies.

Based on study the findings and conclusions, the following recommendations are provided for enhancing the adoption of Charco dam rainwater harvesting technology for livestock and other uses. Firstly, the study recommends that the Ministry of Livestock and Fisheries, along with the Local Government Authority and other stakeholders, should promote awareness and education about the advantages and limitations of Charco dam rainwater harvesting technology among pastoralists. This can be accomplished through targeted extension services, workshops, demonstrations, and information campaigns to enhance their knowledge and understanding of the technology. Secondly, efforts should be made by Monduli District Council in partnership with other livestock stakeholders to explore and promote the potential of Charco dams for multiple uses beyond livestock watering, through income generation activities like fish keeping, and vegetable cultivation to enhance the viability of adopting the technology. Lastly, the provision of subsidy services and an increase in the number of extension visits for pastoralist households should receive top priority from policymakers such as Local Government Authority, pastoralists and Non-Governmental Organizations to enhance the adoption of Charco dams.

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