Determinants of adoption decisions of water harvesting structures among pastoral areas of Kenya

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Abstract

Background: The arid and semi-arid lands are affected inherently by unpredictable rainfall and frequent droughts, which are exacerbated by climate change. This has resulted in deterioration of land resources, leading to forage and water shortages that negatively impact on livestock productivity. To cope with these climatic hazards that affect agricultural production and food security in pastoral areas, on farm adaptation strategies such as water harvesting initiatives are being supported by development agencies and governments. Some of these strategies have not been able to produce the desired levels of productivity and thus have failed to improve the welfare of the pastoral communities or prevent rangelands from deteriorating due to low adoption rates at household level.

Results: This study determined social, economic and institutional factors influencing the adoption of water harvesting systems at household level in pastoral areas of Tana River County of Kenya. The data was collected through household survey, focus group discussions and key informant interviews. The results show that access to extension services and training, monthly income level, main source of livelihood, land tenure system, membership in community groups and availability of active farm labor significantly influenced the adoption of water harvesting structures which need a combination of technical efficiency with low cost and acceptability to pastoral communities.

Conclusion: Pastoralists therefore need to be mobilized and trained on how to construct and use water harvesting structures and sensitized on the potential socioeconomic benefits of adopting them.

Key words: Drylands, Water harvesting, Adaptive strategies, Pastoralism
Background

Drylands make about 40% of the global land surface (Sutie et al., 2005) and constitute approximately 69% of the world’s agricultural land (FAO, 2009). They are important habitats for wild flora and fauna as well as for domestic livestock (Osano et al., 2013). Drylands are predominantly used for pastoralism, which is a low external input subsistence system characterized by extensive livestock production (Galvin, 2009). The system is grounded on a strategic exploitation of resources that are non-uniformly distributed in space and time (Wasonga et al., 2003). The spatio-temporal variability in water and pasture availability influences mobility and settlement patterns of pastoral communities leading to the development of pastoralism as the most suitable livelihood option in the arid and semi-arid areas (Galvin, 2009).

Pastoralists are confronted with a variety of risks that constantly disrupt their livelihoods and devastate assets (Wasonga, 2016). These risks, coupled with limited and increasingly ineffective risk management options, underlie vulnerability in pastoral systems. Some of the challenges facing the pastoral communities include land tenure changes, diminishing grazing resource base, frequent droughts which undermine pasture and livestock productivity (Gao et al., 2009). Recurring droughts have a direct negative impact on natural pasture growth, often resulting in lack of fodder and consequent economic loss for livestock owners that may reach disaster levels. Vulnerability, reserves, economic strength and access to resources are key elements of drought-coping ability (Downing and Bakker, 2000).

Traditional drought-coping mechanisms of pastoralists, such as splitting the herd in various groups spread over the community under the care of relatives seem to have become less effective due to socioeconomic and political changes. In this context, drought contingency planning is gradually receiving more attention as an important strategy to lessen the impact of droughts (Wilhite, 2000). Such planning can occur both at government and at household or pastoral enterprise levels. It invariably involves the formation of reserves, whether of pasture or water (Bruins, 2000) in the wake of climate change variability.

The agro-pastoral communities’ capacity to cope with and adapt to these changing conditions in climate has further been compounded with the wider social and institutional context they live in.
Human and livestock population growth has increased pressure on natural resources in pastoral areas (Omollo et al., 2018). This, coupled with the loss of land and water resources to non-pastoral use and interruption of migration routes, leaves livestock keepers with fewer accessible feed and water resources (Lutta et al., 2019). It also impairs their traditional ways of coping with drought conditions. In view of these challenges, some agropastoralists in Tana River County, Kenya have adopted various strategies to cope with climate hazards that affect agricultural production and food security. According to MoALF (2016) at least 11% of pastoralists have adopted several on-farm and off-farm adaptation strategies in Tana River County. Some adaptations are specific to certain value chains whereas others cut across value chains. On farm adaptation strategies include water harvesting initiatives which are being advocated for mainly by development agencies and the county government and sometimes farmer groups. The water, harvested from erratic rains which sometimes may result in flooding, is used for domestic and irrigation purposes. The strategy involves construction of water conservation structures such as Zai pits, water pans, shallow wells and water tanks at household levels (GoK, 2014).

Water harvesting structures is especially relevant to these semi-arid areas where the problems of environmental degradation, drought and population pressures are most evident. Harvesting runoff water can be a significant drought mitigation strategy at the local level. Runoff water is often available at household level, an important factor for enhancement of water security due to the fact that a significant part of tropical rains is lost as runoff, potentially causing erosion (Kalungu et al., 2015). Widespread adoption of water harvesting structures by the local population is the only way that significant areas of rangeland can be treated at a reasonable cost on a sustainable basis (Ahmed et al., 2013). Harvesting of water which would otherwise flood off is a case of preparedness and mitigation planning, as the presence of such harvesting structures can make a local pastoral household better prepared to mitigate drought by managing the reduced input of rainwater more intensively and efficiently (Sidibe, 2005; Matata et al., 2010).

Various water harvesting techniques, including construction of Zai pits, water pans and shallow wells have been used to capture the little rainfall received in arid and semi-arid areas to support pasture and crop production (GoK, 2014; Kalungu et al., 2015). They are promoted to prevent soil erosion by reducing runoff especially in sloppy terrain of rangelands and improve infiltration of water into the soil (Oweis, 2016; Appels et al., 2016). However, the construction of water
harvesting structures by the agro-pastoral community is not widespread, partly because their ecological and socio-economic benefits have not been fully authenticated. With above backdrop, the present study sought to determine socio-economic factors affecting the adoption of water harvesting structures as tools for harnessing water for improved pasture production in semi-intensive agro-pastoral systems of Tana River County.

Methodology

Study Area

The study was done in Tana River County (Figure 1) which covers 38,682 Km² in Kenya’s coastal region. River Tana forms the Tana River Delta wetland that covers about 1,300 km² and supports more than 100,000 inhabitants (Leauthaud et al., 2013). The county is largely rangeland, receiving low and erratic convectional rainfall. The average annual rainfall is about 280 - 900 mm (GoK, 2014). Rainfall is bimodal; the long rains come from March to May and the short rains take place from October to December. The temperature ranges from a minimum of 23° C to a maximum of 38° C (KIRA, 2014).

Despite the dry conditions, agriculture is the main income-earning activity in the county, contributing roughly 82% to the household incomes (GoK, 2013). However, only 6% of the total land is under crop farming, mostly in the riverine area of the Tana River County, as the mainland is drier and mostly dedicated to livestock farming. With the economic livelihoods of the county being closely tied to agriculture and climate, the hot and dry conditions make the areas away from the Tana River highly vulnerable to years with low precipitation. The riverine and delta areas are highly vulnerable to flooding in years with high precipitation.
A multi-stage sampling procedure was used in the selection of a representative sample. All the three sub-counties of Tana River County namely; Bura, Galole and Garsen inhabited by the agro-pastoralists were purposively selected in the first stage of sampling. The second stage involved a systematic random sampling to select five locations from each sub-county. At the third stage, sampling narrowed down to two smaller administrative units (sub-locations) within each location. Simple random sampling technique was used to select 10 respondents from each sub-location for the study to give a total of 300 respondents. Semi-structured questionnaire was used to collect data on the adoption of water harvesting among the pastoral communities. Pre-testing of the questionnaire was administered through face to face interviews in the targeted communities to test its validity with farmer's conditions before the actual data collection. A total of 50 households were interviewed during the pretesting of the questionnaire. Minor modifications were done through feedback from household interviews and with participation of a multidisciplinary team. A total of 12 focus group discussions were conducted covering, four in each sub-county with 10-12 persons. This also included discussions with 24 key informants involving individuals from institutions that have vested interest in the natural resource management and livelihoods of communities from the county.
Data analysis

Since general trends were the main focus in this study, descriptive statistics using frequency distributions, and cross-tabulations were used to display relationships in the data. The \textit{t-test} and \textit{chi-square} statistics were used to test for significance in differences in the socio-economic characteristics of those who adopted water harvesting structures and those who did not. \textit{Chi-square} test was used for nominal data with categorical variables while \textit{t-test} was used to test the differences in means of the continuous variables. The decision to adopt or not adopt a particular water harvesting structure is a binary decision that can be analyzed using binary choice models. Dichotomous outcomes such as adoption or non-adoption is related to a set of explanatory socio-economic variables that are hypothesized to influence the outcome (Neupane et al., 2002) and can be estimated using probit, logit and linear probability (Omollo et al., 2018). In this study, a logistic regression procedure using maximum likelihood estimation (Kmenta, 1986) was used to estimate the probability of a water harvesting structure being utilized. The Statistical Package for Social Sciences (SPSS version 25) software was used in the estimation of the model (Norusis, 2008). A multivariate binary logit model was therefore used because of consistency of parameter estimation associated with the assumption that error term in the equation has a logistic distribution (Ravallion 2001). The adoption variable is dependent on other variables of the respondent such as age, gender, level of education and income, source of livelihood, and extension information.

The probability of adopting the water harvesting systems at different level of the independent variable is estimated as:

\[ P_i = E(Y = 1 | X_i) = \frac{1}{1 + e^{- (\beta_1 + \beta_2 X_i)}} \]  \hspace{1cm} (1)

Where \( Y = 1 \) means the respondent adopted the water harvesting systems, while \( X_i \) is a vector of explanatory variables, and \( e \) is the base of natural logarithm.

Equation 1 can be re-written as

\[ P_i = \frac{1}{1 + e^{-z_i}} \]  \hspace{1cm} (2)

Where \( Z_i = \beta_1 + \beta_2 X_i \)

Equation (2) represents a cumulative logistic distribution function. The \( P_i \), given in equation (2) gives the probability that the respondents adopted the systems while \((1 – P_i)\), is the probability that all the households adopted the systems.
\[ 1 - P_i = \frac{1}{1 + e^{zi}} \] .................................................. (3)

Equation (3) can be simplified as:

\[ \frac{P_i}{1 - P_i} = \frac{1 + e^{zi}}{1 + e^{-zi}} = e^{zi} \] .................................................. (4)

\( \frac{P_i}{1 - P_i} \) is the odds ratio that the households adopted the water harvesting systems. Hence the natural log of equation (4) can be expressed as shown in equation 5:

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

Where \( L \) represents the log of odds ratios which is in linear form in \( X \) as well as in the parameters, therefore, the logit equation can be specified as in equation 6.

\[ L_i = \left( \frac{P_i}{1 - P_i} \right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon_i \] .................................................. (6)

Where:

\( X = \) is a vector of socio-economic factors influencing households’ ability to adopt

\( \beta = \) is a vector of coefficient to be estimated

\( \epsilon = \) is the error term assumed to be normally distributed with a mean of zero and variance \( \delta^2 \)

The presence of multicollinearity and heteroskedasticity in the independent variables were tested. For multicollinearity, a linear correlation coefficient which measures the direction of a linear relationship between two variables was used (Maddala 2001). To quantify the severity of multicollinearity, the Variance Inflation Factor (VIF) was used to measure how much the variance of the estimated regression coefficient is increased because of collinearity as shown in equation 7.

According to Greene, (2002) if VIF \((\beta_i)>5\), then multicollinearity is high.

\[ VIF = \frac{1}{1 - R_i^2} \] ................................................................. (7)

Explanatory variables and their expected effects

Factors that influence the adoption of water harvesting structures in arid and semi-arid areas can be categorized into two: socioeconomic factors and institutional factors. The socioeconomic factors include age, gender, education, household size, herd size and income while institutional factors include membership in community groups, access to extension services and land tenure (Table 1).
**Age:** According to the theory of human capital, young heads of household have a greater chance of being taught new knowledge (Sidibe, 2005) and, hence, are better prepared for the adoption of technological innovations (Akroush, 2017). Since labor and credit markets are imperfect, older household heads lacking the labor necessary for construction and frequent maintenance of conservation structures may not easily adopt the water harvesting structures (Zegeye et al., 2001). Young people may also be more receptive to new ideas and are less risk averse than the older people (Barret et al., 2007). Thus, we expect age of the household head to have a negative effect on the adoption.

**Gender:** Gender represents differences in adoption orientation between male and female heads of households. Gender determines access to resources and assets particularly in pastoral context (Omollo, 2010). Male headed households have more access to productive resources such as land and livestock compared to female counterparts who are constrained by low access to natural resources (Wasonga, 2009). More male headed households were therefore expected to adopt the water harvesting structures compared to their female counterparts.

**Education:** Household head’s formal education has a positive effect on adoption of water harvesting structures because it enhances management skills and ability to utilize information (Ahmed et al., 2013). Education would expose one to technical skills and knowledge and therefore creates awareness and enhances adoption of water harvesting systems (Hatibu, 2003). Education is therefore posited to increase the adoption rate.

**Household size:** Household size may either have a positive and a negative influence on adoption of water harvesting structures. A larger household may have cheap and adequate labor for construction and management of water harvesting structures as opposed to a household with no cheap labor (Alene et al., 2008). Consumption needs for a larger family may also be high hence requiring more resources for the household to meet their family needs hence reducing disposable income available for construction of water harvesting structures (Ahmed et al., 2013).

**Source of livelihood:** Source of livelihood is expected to have a positive influence on the adoption of water harvesting structures. Pastoralists whose source of livelihood is mixed livestock and crop production are more likely to adopt the water harvesting structures due to its environmental benefits of water conservation for livestock and crops (Manyeki et al., 2013) than those who have other alternatives as their primary source of livelihood.
**Herd size:** Herd size is expected to have a positive influence on the adoption of water harvesting structures. In pastoral communities, larger herd sizes are associated with more wealth (Omollo et al., 2018). Livestock is a productive asset that generates future income to the households through milk production and calving, and are easily sold in terms of the need for cash (Muthee, 2006) which means such households can easily afford to construct water harvesting structures. The coefficient for the herd size is therefore expected to be positive.

**Household income:** Household income may have both a positive influence on adoption of water harvesting structures. A household with more income means they have enough capital to venture into more capital-intensive activities such as water harvesting structures (Zegeye et al., 2001). Pastoralists who earned more income per month are more likely to afford water harvesting structures than those who earned less. This could be attributed to the budget constraints for those who earn less where the construction of water harvesting structures is beyond their budget set with those with higher income affording to pay with ease.

**Extension information:** Extension services provide the requisite technical assistance and skills required for the construction and management of the water harvesting structures (Khalid et al., 2017). This increases farmers’ knowledge and perception of the merits of water harvesting structures through better access to technical information and training provided by the extension personnel (Akroush et al., 2017). Access to extension information is therefore hypothesized to increase the adoption of water harvesting structures.

**Land tenure:** Land tenure can have a variety of influences on the adoption of water harvesting structures. There are three types of land tenure in the study area: private, community and public land. On the one hand, it may be that lack of tenure means that people are reluctant to invest in water harvesting structures on land which they do not formally own (Kisimba et al., 2006). Where land ownership and rights of use are complex it may be difficult to persuade one to improve land that someone else may use later (Ahmed et al., 2013). A household who privately own land is more likely to adopt the water harvesting structures. On the other hand, community ownership would mean the community can pool their resources in terms of manpower to construct the water harvesting structures with ease.

**Membership in community groups:** According to McKague et al., (2009), community social groups improves cooperation among the pastoralists, which enables them to pull their resources
together and make proper decisions in the conservation of natural resources hence increasing their adoption (Omollo et al., 2018). Farm groups provide social capital, and help farmers to pool resources for collective action as well as increasing the capacity of members to access services such as credits, extension and information.

### Table 1: Explanatory Variables used in the empirical Binary Logistic Model

| Variable                  | Description                                   | Type of measure                                                                 | Expected sign |
|---------------------------|-----------------------------------------------|---------------------------------------------------------------------------------|---------------|
| **Dependent variable**    |                                               |                                                                                 |               |
| Adoption                  | Whether a HH adopted or not                   | Dummy (1 if yes, 0 if No)                                                       |               |
| **Explanatory variables** |                                               |                                                                                 |               |
| Age                       | Age of the HH head                            | Years (1, 2, 3)                                                                 | -             |
| Gender                    | Gender of the HH head                         | Dummy (1 if male, 0 if Female)                                                   | +/-           |
| Education                 | Education level of HH head                    | 0 = None, 1= Primary, 2=Secondary, 3= College                                    | +             |
| Monthly Income            | Total income received by a HH in a month      | 1=<10,000, 2=10000-20000, 3=20,000-30,000, 4=>30000                           | +             |
| Land tenure               | Status of land ownership                      | 1= Private, 2= Community, 3= Public                                               | +/-           |
| Membership in farm group  | Registered member in a farmers group          | Dummy (1 if yes, 0 if No)                                                       | +             |
| Extension                 | Extension information and training            | Dummy (1 if yes, 0 if No)                                                       | +             |
| Active labour             | Readily available labour force                | Dummy (1 if yes, 0 if No)                                                       | +             |
| Credit                    | Access to agricultural credit                 | Dummy (1 if yes, 0 if No)                                                       | +             |

### Results and discussion

Tables 2 and 3 show the socioeconomic characteristics of the sampled respondents. The results show that those who adopted the water harvesting structures (N = 96) were associated with a significantly ($t_{(300)} = 3.7$, $p = 0.00$) larger herd size (Mean TLU 28.9 ± 16) compared to non-adopters (N = 204) who had a smaller herd size (Mean TLU = 21.9 ± 12.9). Non-adopters were
slightly older (Mean = 44.7 years) than the adopters (Mean = 42.6 years). However, the mean age difference between the adopters and non-adopters was statistically insignificant (t_{300} = -1.36, p = 0.17). Those who adopted had a significantly (t_{300} = 3.6, p = 0.03) larger average household size than the non-adopters (Table 2). Majority (82.3%) of those who adopted the water harvesting structures were male headed households, while more than half (55.9%) of non-adopters were female headed households. Gender was statistically significant (χ² = 19.8, df = 1, p < 0.000) indicating male headed households were more likely to adopt the water harvesting structures compared to their female counterparts (Table 3).

Table 2 Socio demographic characteristics of the sampled respondents

| Characteristic          | Adopters | Non-adopters | t-ratio | Sig  |
|-------------------------|----------|--------------|---------|------|
|                         | Mean     | Standard deviation | Mean | Standard deviation |         |
| Age (years)             | 42.6     | 14.5         | 44.7    | 11.8    | -1.36 | 0.17 |
| Household size (number family members) | 7.2     | 1.8         | 6.4     | 1.8     | 3.6** | 0.03 |
| Herd size (TLU)         | 28.9     | 16           | 21.9    | 12.9    | 3.7*** | 0.00 |

***: Significant at 1% level; **: Significant at 5% level; *: Significant at 10% level.

Significantly (χ² = 106.9, df= 1, p = 0.000) most of the adopters (86.5%) were members of community groups compared to only 23% of non-adopters. There was no significant difference in the education levels of the adopters and the non-adopters (χ² =1.09, df = 3, p = 0.78) with 65.6% and 68.1% of adopters and non-adopters having had basic primary education respectively. The results also show that a significant (χ² =96.2, df = 1, p = 0.000) majority (76%) of the adopters had access to extension services compared to non-adopters (17.6%). The main source of livelihood for majority (84.4%) of the adopters was mixed livestock and crop production compared to most of the non-adopters (60.3%) whose main source of livelihood was cattle keeping (χ² =146.9, df = 4, p = 0.000). Majority of the adopters (62.5%) had private land ownership compared to non-adopters (19.1%). The differences are statistically significant (χ² =155.94, df = 1, p = 0.000) showing that land tenure is likely to influence the adoption of water harvesting structures. Significantly (p = 0.000), most of the adopters had access to credit (81.2%) and active labor
(87.5%) compared to non-adopters. Monthly income levels were significantly ($\chi^2 = 105.8, df = 4, p = 0.000$) different between the adopters and the non-adopters with majority (77.5%) of the adopters making at least more than Ksh. 10,000 a month compared to non-adopters (14.6%). These results show that income, extension information, land tenure, availability of active labor, membership in farmer groups, access to farm credits, gender of household head, herd size and household size are likely determinants of the adoption of water harvesting structures in pastoral areas.

Table 3 Descriptive characteristics of respondents

| Characteristics          | Category        | Adopters          | Non-adopters        | $\chi^2$ | Sig  |
|-------------------------|-----------------|-------------------|---------------------|----------|------|
|                         | Frequency       | Proportion (%)    | Frequency           | Proportion (%) |     |
|                         | (N = 96)        |                   | (N = 204)           |           |      |
| Gender of HH head       | Male            | 79                | 90                  | 19.8***  | 0.00 |
|                         | Female          | 17                | 114                 |           |      |
| Education               | None            | 33                | 65                  | 1.088    | 0.78 |
|                         | Primary         | 52                | 108                 |           |      |
|                         | Secondary       | 10                | 26                  |           |      |
|                         | College         | 1                 | 5                   |           |      |
| Main source of livelihood | Employment    | 0                 | 7                   | 146.9*** | 0.00 |
|                         | Cattle keeping  | 12                | 123                 |           |      |
|                         | Farming         | 3                 | 25                  |           |      |
|                         | Business        | 0                 | 23                  |           |      |
|                         | Livestock and crop production | 81 | 84.4 | 26 | 12.7 |
| Monthly income (Ksh)    | <10,000         | 46                | 82                  | 105.8*** | 0.00 |
|                         | 10,000- 20,000  | 116               | 12                  |           |      |
|                         | 20,000-30,000   | 37                | 2                   |           |      |
|                         | >30,000         | 5                 | 0                   |           |      |
| Land tenure             | Private         | 60                | 39                  | 155.94***| 0.00 |
|                         | Community       | 36                | 165                 |           |      |
| Farmer groups           | Member          | 83                | 47                  | 106.9*** | 0.00 |
|                         | Non-member      | 13                | 157                 |           |      |
| Extension               | Available       | 73                | 36                  | 96.2***  | 0.00 |
|                         | Not available   | 23                | 168                 |           |      |
According to Scott et al., (2008), the decision to adopt a new idea, behavior, or product is an active and dynamic process with interactions between the individual, situational factors and contextual factors as well as attributes of the innovation itself. The key to adoption is that the person must perceive the idea, behavior, or product as new or innovative. Rogers' Diffusion of Innovation Theory 1962 seeks to explain how new ideas are adopted, and this theory proposes that there are five attributes of a new idea or approach that effect adoption: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). An even point Likert scale (Akroush et al., 2017) was used to assess the above-mentioned characteristics of adopters and gauge their attitudes by asking the extent to which they agree or disagree with the awareness of the need for water harvesting structures, decision to adopt or reject their initial and continued use (Table 4).

**Table 4 Perception of respondents about the water harvesting structures**

|                                      | Adopters | Non-adopters | \(\chi^2\) | Sig |
|--------------------------------------|----------|--------------|------------|-----|
| Relative advantage in reducing       |          |              |            |     |
| agricultural risks                   | 81.2     | 18.8         | 25.5       | 74.5| 82.66*** | 0.00 |
| Compatible with existing needs and   | 77.1     | 22.9         | 72.5       | 27.5| 0.70     | 0.481|
| socially acceptable                  |          |              |            |     |
| Complex and difficult to understand  | 12.5     | 87.5         | 83.3       | 16.7| -0.68*** | 0.00 |
| and use                              |          |              |            |     |
| Triable and easy to follow and       | 55.2     | 44.8         | 53.9       | 46.1| 0.044    | 0.901|
| implement                            |          |              |            |     |
| Observable benefits                  | 80.2     | 19.8         | 78.9       | 21.1| 0.066    | 0.88 |

***: Significant at 1% level; **: Significant at 5% level; *: Significant at 10% level
Table 4 shows that majority of the adopters (81.2%) believe that water harvesting structures have relative advantage in reducing agricultural risks by being more productive and efficient in conserving water compared to non-adopters (25.5%). There is however no significant difference ($\chi^2 = 0.7$, df = 1, $p = 0.481$) between the adopters and non-adopters who believe that the water structures are important in regard to their water needs. This means that in terms of the compatibility of water harvesting structures, all the adopters and non-adopters believe that the water harvesting structures are consistent with their needs, and experiences hence they are essential. For water harvesting structures such as water pans and Zai pits, this entails directing runoff from some external catchment area to where it is desired. In ASALs areas where biomass water requirements are higher than available rainfall, water harvesting can help to satisfy their water needs. In these areas where soils often cannot absorb the heavy downpours, ground catchment rain water harvesting acts as a tool to increase infiltration and decrease runoff. This thus helps to improve yield during a normal year, and more importantly, helps to prevent crop failure when rains are below the seasonal average.

Regarding the complexity and difficulty in constructing water harvesting structures in their farms, significantly ($\chi^2 = -0.68$, df = 1, $p = 0.00$), most of non-adopters (83.3%) believe that it is quite difficult to construct the structures and therefore needs more technical skills and knowledge compared to 12.5% of the adopters. All the adopters and the non-adopters agreed that the water harvesting structures can be tried in demonstration plots before being implemented ($\chi^2 = -0.044$, df = 1, $p = 0.901$). Demonstration farms are the most effective extension education tools for demonstrating technical skills including proper citing of the catchment areas, formulation of technical designs, and building of the structures (Moser and Barrett, 2006). For pastoralists, demonstration plots provide an opportunity to demonstrate and teach appropriate water harvesting technologies, as well as venues to test new methods side by side with traditional methods. Although they require considerable time and effort, the payback comes when farmers more readily adapt practices, they perceive to be effective and appropriate under local conditions (Scott et al., 2008). Majority of the respondents (79.3%) agreed that water harvesting structures have observable environmental benefits with no significant difference ($\chi^2 = -0.066$, df = 1, $p = 0.088$) between the adopters (80.2%) and non-adopters (78.9%).
Binary logit model

Table 5 shows that the mean VIF for exploratory variables included in the model was 1.33 which is lower than 5 hence no multicollinearity. All the independent variables used were therefore uncorrelated and independent making it easier for the model to estimate the relationship between each independent variable and the dependent variable independently.

Table 5 Multicollinearity test for the explanatory variables

| Model variables                  | Tolerance | VIF |
|----------------------------------|-----------|-----|
| Gender of respondent             | .810      | 1.23|
| Age of respondent                | .782      | 1.27|
| Education level                  | .945      | 1.05|
| Main source of livelihood        | .573      | 1.74|
| Average monthly HH income        | .571      | 1.75|
| Member of farmers’ group         | .682      | 1.46|
| Extension services               | .664      | 1.51|
| Land tenure                      | .804      | 1.24|
| Easy access to credit            | .759      | 1.32|
| Availability of Active labor     | .754      | 1.32|
| Mean VIF                         |           | 1.33|

The level of significance of each variable was tested using the null hypothesis that these explanatory variables have no effect on the decision to adopt water harvesting structures. The results in Table 6 show that the model is statistically significant (p = 0.00) and the independent variable explains 87.9% ($R^2 = 0.879$) of the variation in households’ decision to adopt the water harvesting structures in the study area. Out of the ten variables tested in the model, access to extension services and training, monthly income, main source of livelihood, land tenure, membership in community groups and availability of active labor were statistically significant.

Households with better economic standing, measured by the total value of their monthly income are more likely to adopt the labor-intensive technologies such as water harvesting structures. Households with more disposable income are able to afford hired-in labor required for construction and management of water harvesting structures. Labor cost for construction and maintenance of water harvesting structures is the most important factor to be considered, which determine if a technique will be widely adopted at the individual farm level (Manyeki et al., 2013). The results
show that many farmers in the study area were low income earners. This means that they may not afford the manpower available to move large amounts of earth that is necessary in some of the large water harvesting systems such as water pans (Rosegrant et al., 2002). Akudugu et al. (2012) reported that modern agricultural production technologies that were capital intensive were less likely to be adopted. This explains the positive and significant influence of monthly income to the adoption of water harvesting structures. Adoption propensity of most technologies increases with the percentage increase in disposable income because relatively rich households are able to afford labor and the inputs used to adopt the technologies, are less risk averse and perhaps reflecting economies of scale (Tigabu et al., 2018).

Although most households in pastoral communities rely on family labor, exchange and hired labor is relatively used more in labor intensive technologies (Lugusa, 2015). This means that households with access to exchange or hired labor will be in a better position to adopt water harvesting structures. According to Bardasi et al., (2011), the adoption of labor-intensive technologies might also put a greater burden on family labor, as their time might be reallocated from other household’s income generating activities. Therefore, households without access to family labor or constrained by imperfections in credit and labor markets might face difficulties in hiring (Vandercasteelen et al., 2018) or reallocating family labor away from wage employment to additional farm activities (Barrett et al., 2004; Takahashi and Barrett, 2013). As construction of water harvesting structures is very labor intensive, adoption might be difficult for labor-constrained households which are unable to invest more person-hours of labor in water harvesting structures. This could explain why our results show that labor has a positive and significant effect on the adoption of water harvesting structures.

Table 6 Parameter estimates of Binary Logit model

| Variable                | $\beta$ | S. E  | Wald | Exp ($\beta$) | $P$ value |
|-------------------------|---------|-------|------|---------------|-----------|
| Gender                  | -1.102  | .748  | 2.171| .332          | .141      |
| Age                     | -.011   | .025  | .181 | .989          | .671      |
| Education               | -.037   | .514  | .005 | .963          | .942      |
| Main source of livelihood| .659    | .241  | 7.504| 1.934**       | .006      |
| Monthly income          | 2.410   | .630  | 14.645| .090***       | .000      |
| Land tenure                      | Access to credit | Active farm labour | Member of farmer group | Constant       |
|---------------------------------|------------------|--------------------|------------------------|---------------|
| -2.220                          | .556             | 3.623              | 3.711                  | 21.149        |
| 1.099                           | 1.222            | .827               | .871                   | 4.222         |
| 4.081                           | .207             | 19.189             | 18.157                 | 25.094        |
| .109*                           | .574             | .027***            | .024***                |               |
| .043                            | .649             | 0.000              | 0.000                  |               |

**Statistical significance level:** ***1%, **5%, *10%; Chi-square (df = 10) = 296.49 (p < 0.000);** 
2\(\log\) likelihood = 79.63; Cox and Snell \(R^2 = 0.628;\) Nagelkerke \(R^2 = 0.879\)**

Adoption of water harvesting structures require technical skills including proper citing of the catchment areas, formulation of technical designs, and building of the structures. Therefore, for effective implementation and subsequent adoption of water harvesting technologies, farmers would require technical know-how and skills (Khalid et al., 2017). In addition, farmers need to be mobilized and trained on the use of rainwater harvesting technologies and sensitized on the potential socioeconomic benefits of adopting them (Adesina and Chianu, 2002). This is where extension services come in handy. The results show that access to extension services has a positive and significant effect on the adoption of water harvesting structures. Extension officers are able to contextualize new ideas and innovations to suit local realities (Ahmed et al., 2013). It is tempting to assume that a system which works in one area will also work in another, superficially similar, zone. However, there may be technical dissimilarities such as intensity of rainfall and distinct socio-economic differences hence the need for extension officers who understand the local area to contextualize technologies for easier adoption. Extension services in the study area are provided by the county government and development agencies who however last in an area only for the short duration of the project. This leaves the county government with the sole mandate of providing long term extension services. However, according to focus group discussions and key informant interviews, the number of farm visits by agricultural officers has been significantly reduced in the past years due to low budgetary allocation and poor road network in the county. In addition, farmers are reluctant to adopt new technologies due to sociocultural factors such as reluctance to diversify into crop production by the pastoral community, and lack of evidence of impact of these technologies on production and incomes through demonstration plots. Extension involves field visits, focus group discussions, and workshops on aspects related to water conservation and other
relevant value chains. These include: crop planting and growing times, input utilization and value addition, and amount of product to sell on the market as well as fodder establishment and conservation (Kidake et al., 2016). Improved participation, mobilization and training of the local people would create an understanding of water harvesting technologies and make room for more adoption.

There is significant relationship between land tenure and the adoption. From the descriptive analysis results, majority of pastoralists who adopted the water harvesting structures privately owned their land. Land tenure issues can have a variety of influences on water harvesting projects. In a communally owned land, people may be reluctant to invest in water harvesting structures on land which they do not formally own. Where land ownership and rights of use are complex it may be difficult to persuade one to improve land that someone else may use later. To the contrary, Akroush et al., (2017) found that in Jordanian arid lands, the adoption decreased when land was privately owned, and given the fact that the upfront cost of water harvesting technologies was too big and thus farmers were more interested to invest as a group or on communal lands in order to share the cost of adoption.

Membership in community groups significantly increased the adoption of water harvesting structures. Community groups play a significant role in rural development particularly in arid and semi-arid areas by building on the knowledge that underlies socio-cultural practices when going for new development opportunities. Raphael et al., (2020) while studying the group dynamics in pastoral areas affirmed that groups are open to adopt external knowledge when it helps them to improve their practices. Community groups improve cooperation among the pastoralists which enables them to pull their resources together and make collective decisions in the conservation of natural resources (Njuki, et al., 2008; McKague et al., 2009). This could explain why membership in community social groups was found to be positive and significant. According to Rijn et al., (2012) social capital plays an important role in technology diffusion and adoption because local people are more likely to be motivated to participate with genuine commitment to collaborating with institutional actors for initiatives that lead to sustainable changes in agriculture and resource management. The positive correlations therefore imply that adoption of water harvesting structures increase with increase in the levels of group involvement. This is also similar to the findings of Matata et al. (2010) who in their study on socio-economic factors influencing adoption of
improved fallow practices among small scale farmers in Tanzania found out that membership in farmers groups significantly influenced adoption of improved fallows.

**Conclusion**

Socio-demographic, economic and institutional characteristics should be considered in the dissemination and widespread adoption of water harvesting structures at household level. Few water harvesting projects have succeeded in combining technical efficiency with low cost and acceptability to the local farmers or agro-pastoralists. This is partially due to the lack of technical "know how" but also often due to the selection of an inappropriate approach with regard to the prevailing socio-economic conditions. The technical aspects of rainwater harvesting systems have been stressed in pastoral areas though these results show that it takes more than just the engineering aspects. The results demonstrate that the adoption process of water harvesting structures has a social element, and collegial interactions. Pastoralists require technical know-how and skills, capital, and organizational support for the successful adoption and use of water harvesting systems. Socio-cultural aspects are, therefore, paramount and will affect the success or failure of the technique implemented. Enhancing our understanding of these influencing factors could provide valuable information to guide dissemination efforts and thereby increase the efficiency of innovation implemented.

Therefore, there is need to design and develop alternative effective policy instruments and mechanisms, strong institutional options for extension services, technical assistance, training and capacity building that will facilitate adoption of water harvesting structures through participatory practices to ensure better fit to the needs of pastoralists. Creation of strong networking among different institutions related to applying water harvesting structures and involvement of civil societies, public and private financial institutions and support services could be an example of mechanisms to enhance the adoption of water harvesting structures in pastoral areas of Kenya.
Declaration

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Availability of data and material
All data generated and analyzed during this study are included in this published article

Competing interests
The authors declare that they have no competing interests

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Authors' contributions
AIL contributed to the conception and design of the study, collected the data, carried out analysis and interpretation of data, drafted the manuscript and submitted the approved version. OVW contributed to the conception and design of the study, assisted in the interpretation of the data, revised the manuscript for intellectual content and gave approval of the version to be published. LWR contributed to the conception of the study, facilitated the acquisition of funds for the study, coordinated the data collection process, revised the manuscript critically for intellectual content and gave approval of the version to be published. MMN contributed to the conception and design of the study, guided the data analysis process, revised the manuscript for intellectual content and
gave approval of the version to be published. FKS contributed to the conception of the study, revised the manuscript for intellectual content and gave approval of the version to be published. All authors read and approved the final manuscript.
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22
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