Ghana Journal of Geography

journal homepage: https://www.ajol.info/index.php/gjg/ https://journals.ug.edu.gh/index.php/gjg/

Evaluation of Water Access for Livestock Index in Range Lands of Semi-Arid Areas of Monduli District, Arusha Region, Tanzania.

Fredrick A. Mfinanga[1*], Monica Francis Timbuka[2] & Stephen Bishibura Erick[2]

[1]Institute of Rural Development Planning, Department of Development Finance and Management Studies, P.O BOX 11759, Mwanza Tanzania.
[2]Institute of Rural Development Planning, Department of Regional Development Planning P. O. BOX 11759, Mwanza, Tanzania.

article info

Article history:
Received 18th March 2024
Accepted 11th November 2024
Published 31st December 2024

Keywords:
level,
water access index,
semi-arid areas,
rangelands.

abstract

Various frameworks with different indicators are employed to evaluate water access in households and communities. However, approaches specifically designed for determining water access for livestock by pastoralist households in semi-arid areas are limited. The study was conducted in Monduli District, Tanzania. The objective of the study was to establish the levels of water access for livestock by pastoralist households in rangelands of semi-arid areas. Through a household survey, a semi-structured questionnaire was administered to 367 households in seven villages. Data were analysed by using frequencies and counts. In addition, multinomial logit latent class regression models were used to determine the levels of water access for livestock by household. The study found four sources of water access for livestock; namely the leading class of high access of water with low quality 31.4%, followed by the low level of water access with multiple use 26.43%. The lowest level is the category of high access, but less affordable with multiple use 24.5% and 17.7% low access with high quality of water for livestock. The study further showed that Makuyuni ward had higher water access than Moita. The study recommends construction of both improved and unimproved water sources for livestock such as boreholes and charco dams through collaboration between the community and Monduli District Council.

Introduction

Water access for livestock is a major challenge facing pastoral communities in Sub-Saharan Africa (Boyomo et al., 2024; Nejadhashemi et al., 2022). Approximately 200 inhabitants in Sub-Saharan Africa depend on livestock to support their livelihood (Mapfumo et al., 2021), but climate change affects the water supply in the rangelands of semi-arid areas. In East Africa, the semi-arid rangelands, water access to livestock is a growing challenge that poses dangers to both livestock and pastoralist livelihoods (Johnson et al., 2023; Bogale et al., 2022). The shortage of water for livestock has been associated with declining livestock productivity and increased mortality rate, with mass livestock deaths, testified during droughts across the East Africa region (FAO, 2022). This has major economic importance for pastoralist livelihoods, as reduced herd sizes weaken pastoralists' capacity to uphold traditional mobility in search of water (Duale, 2024). The effects of water shortages exemplify the connected relationship between pastoralists' livestock production in semi-arid rangelands and the dangers of water shortage for livestock.

Pastoralists face water shortage for their livestock, which requires rethinking frameworks for water access. Traditional frameworks are inadequate in pastoral areas due to a lack of reliable environmental indicators for livestock water access (McGahey et al., 2014). Climate change affects traditional mobility-based strategies (Wanjara and Ogembo, 2023; Tugjamba et al., 2023) emphasizing the need to conceptualize water access for livestock through variables such as distance, perception of water quantity, time taken, income, type of water sources and multiple use services.

* Corresponding author.
E-mail addresses: fredrickmfinanga@gmail.com (F. Mfinanga).

http://dx.doi.org/10.4314/gjg.v16i4.6

Several frameworks and indices have been developed to measure water access, but there is no consensus on a universal framework (Majuru et al., 2018). For example, the Millennium Development Goals (MDGs) define water access as the use of an improved water source (Cassivi et al., 2018), while in the Global Sustainable Development Goals (SDGs), water access refers to the use of drinking water from an improved source which is located on the premises, available when needed and free of faecal and priority contamination (Weststrate et al., 2018). In this study, the term "water access" refers to a person's ability to easily access water for production and livelihood.

The first framework measuring and ranking water services was introduced in the 1990s and suggested that water services need to be measured by using five indicators including cost, continuity, quantity, coverage and quality (WHO, 1997). The second framework was introduced in 2003 and focused on four indicators including domestic water quantity, quality, service level, level of health concern and other uses of water including productive uses and amenity uses of water. This framework suggests that the level of water supply is linked to health and livelihood.

Similarly, the third framework, which is a human rights framework for water was established in 2003 with four indicators including availability, quality, accessibility, nondiscrimination and equality (Jensen et al., 2014). This framework suggests that water services should be accessible to all people without discrimination. In addition, this approach highlights the importance of addressing the problem of nondiscrimination and equity while tracking progress in water access across every indicator. In addition, this approach emphasizes the universal and equitable supply of water services by suggesting that access to water is a human right rather than a commodity.

Closely related to the above is the fact that, by the year 2007-2009, a fourth framework known as Multiple Use Services (MUS) was established that took into account several indicators such as distance and the volume of water used in supporting various activities (Renwick et al., 2007). The framework is unique as it considers the elements of economic and wealth generation benefits (Jepson et al., 2023). Likewise, between 2008 and 2009, the fifth framework termed as the “water service ladder” was established by the United Nations with four variables including access, quantity, quality and reliability. This framework suggests that as the people progress up the ladder, they gain better access to water sources that are closer, more convenient, and more reliable, with a consistent and dependable supply. The framework proposed the use of the term "water service ladder", which consisted of three levels: the top level was piped water on the premises (piped household water connection located inside the user's home), the middle level was improved water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs or rainwater collection), and the lowest level includes unimproved drinking water sources such as unprotected dug wells and unprotected springs.

All these above frameworks focused on domestic water access but none of them touches the specific framework for determining water access for livestock in range lands in semi-arid areas (Kayser et al., 2013). This could be due to the marginalization of water services for livestock in rural areas (Mahoo et al., 2015; Mohamed, 2019). Furthermore, some domestic water frameworks have been developed, especially the water security index developed by the Asian Pacific Network for Global Change Research (Assefa et al., 2018); and the water reuse index (Shrivastava and Mategaonkar, 2024, Reynaert et al., 2021). These indexes focused on factors determining the level of domestic water access, but not on livestock. In terms of water use for livestock, indexes developed include livestock water productivity index, and local water management framework (Bosire et al., 2022; Drastig et al., 2021). The livestock water productivity index focused on water use and livestock outputs (Amole et al., 2021; Tulu et al., 2024).

The livestock water productivity index focuses on water used for livestock production; therefore, it has no element of water access for livestock in rangeland of semi-arid areas. Similarly, Hamilton et al. (2020) established a local water management framework that incorporated the previous framework especially the use of the Multiple Use Services (MUS) framework by Renwick et al. (2007). This framework is strong because it is an integrated water service delivery approach and supports the use of multiple indicators to describe water access services (Daly et al., 2021). This framework overcome previous shortcomings observed in the implementation of MDGs (Kayser et al., 2013). However, the framework was applied in areas with abundant water sources where mixed farming takes place including irrigation activities (Hamilton et al., 2020). This study has significant benefits of creating a standardized index for evaluating the level of water access for livestock among pastoralist societies in semi-arid rangelands in Monduli District, Tanzania. The research question that guided this study was as follows:

What is the level of water access for livestock by pastoralist households in rangelands of semi-arid areas? Therefore, this study, aim to establish a standardized index for the measurement of water access for livestock by pastoralist households in rangelands of semi-arid areas of Monduli District in the Arusha Region, Tanzania. The index will serve as a vital tool in promoting sustainable livelihoods, efficient resource management, and informed policy-making, ultimately enhancing the resilience and well-being of pastoralist communities. Moreover, the index will enhance the overall welfare of pastoralist households by securing water resources, reducing the burden on families to find water, and freeing time for other productive activities.

Literature Review and Theoretical Frameworks Underpinning the Study

Millennium Development Goals and Water Access

The Millennium Development Goals (MDGs) were a set of eight international development goals established by the United Nations in 2000 (UN, 2015; World Health Organization & UNICEF, 2017). MDG Goal 7 aimed to ensure environmental sustainability, including a target to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 (UN, 2015). While significant progress was made there are still disparities in access to clean water particularly in developing countries (Oskam et al., 2021; Akoteyon, 2019). The Sub Sahara Africa failed to meet the intended target for accessing drinking water with only 42% of its population getting access to drinking water since 1990 (World Health Organization WHO/UNICEF, 2015; Bolaane et al., 2021). In the Millenium Development Goals, the level of water access was measured by the proportion of the population using an improved water source (World Health Organization & UNICEF, 2017). An improved water source is one that sufficiently shields the source from external pollution and provides easy access to water for household needs (Antunes and Martins, 2020). The focus in MDG was on the type of water sources/services used by the household. Although the accessibility of water services has not met the economic benefits (UNESCO and UNESCO i-WSSM (2019).

Sustainable Development Goals and Water Access

Previous studies have unraveled the important role of water access in livestock production and its direct impact on the achievement of SDG 6 (Magnusson et al., 2022; Campos et al., 2022; Sebo et al., 2022). However, while progress has been made in addressing water access for livestock, several challenges persist. Insufficient infrastructure, inadequate management practices, and limited policy frameworks have hindered the effective provision of water resources to meet the growing demand in the livestock sector (Kariuki et al., 2022; Piemontese et al., 2024; Eeswaran et al., 2022). Furthermore, the impact of climate change on water availability and quality poses additional challenges that require attention (FAO, 2018). Moving forward, it is imperative to enhance interdisciplinary research efforts, strengthen collaborations between stakeholders, and develop innovative strategies to improve water access for livestock, aligning with SDG 6, and promoting sustainable development.

Theoretical Framework Underpinning the Study

This study adopted the WHO-UNICEF Joint Monitoring Programme (JMP) Indicators for Water Supply (Rakotomanana et al., 2020). It is called the water service ladder framework, which focuses on a type of water services received by households categorized into three namely piped water (piped household water connection located inside user dwelling), improved water sources (public taps or standpipe, tube wells or boreholes, protected dug wells, protected springs or rainwater collection) and unimproved water sources (unprotected dug well, unprotected spring, carts with small tank, drum, surface water including river, dam, lake, pond, stream, canal, irrigation channels and bottled water).

The JMP framework is selected because it is the only water service framework supported by data collection, especially primary data collection at scale throughout the world and that can be aggregated and disaggregated at different geographical scales (Kayser et al., 2013). Nevertheless, this framework has been criticized for some weaknesses including the failure to incorporate the element of economic development (Kayser et al., 2013). In addition, the JPM framework has failed to quantify other essential dimensions of water access such as socioeconomic indicators like household income (Ocholla et al., 2022). Thus, a Framework of Multiple Use Services (MUS) by Renwick et al. (2007) was employed to complement the selected framework and other dimensions supported from the literature to address the weakness of the JMP water services framework. Multiple water use services are an integrated strategy for service delivery that consider all of the water demands of a household (Jepson et al., 2023; Zozmann et al., 2022). The dimension of livelihood was used, which captures multiple water use services including drinking, hygiene, bathing, laundry, and cleaning categorized as domestic services and gardening, livestock, irrigation and small enterprises categorized as productive activities.

Other dimensions from the literature reviews were distance (Mati et al., 2005; Niyonzima et al., 2013: Hadush 2018); the use of water and affordability (Kayser et al., 2013; Masanyiwa et al., 2017). In terms of distance, Alemayehu et al. 2023 affirm that distance to the water source is an important indicator for measurement of the quantity of water accessed by household. In addition, the affordability indicator was applied in this study because it is used in realizing access to water as a human right (Kashem et al., 2023). In terms of the indicator, time was applied because most of the households in semi-arid areas were not connected to water services on their premises (Cassivi et al., 2018). Furthermore, this is because the issues related to time in accessing water services were reported in many studies both in urban and rural areas (Nounkeu et al., 2022; Amankwaa et al., 2024; Sesabo, 2024). From the above explanation, the study constructed water access for livestock index (WALI) composed of six indicators namely type of water source, distance walked by livestock to water source, multiple uses of water source used for livestock and income (affordability), time taken during watering livestock and perception on water quantity accessed by pastoralists households.

Definitions of dimensions and indicators for Water Access for Livestock Index (WALI)

Multiple Uses

Refer to the use of water in various domestic and non-domestic activities, especially livestock keeping, irrigation and other productive activities. In this study, uses of water were measured by using multiple uses of water indicators including water use for domestic services, gardening, livestock, irrigation, and small enterprises categorized as productive activities for example brick making and building of houses. These indicators were measured through questions on whether the household the water for livestock was used was also used in other domains especially domestic use, gardening, livestock, irrigation and small enterprises. Multiple water use refers to the practice that considers various requirements of water users by taking into account the different water sources and acts as a starting point for communities to monitor and manage water for different investments (Van Koppen, 2006). This dimension is selected because it has been tested in rural Sub- Saharan Africa to understand the benefits and costs of the application of single versus multiple uses of water in rural areas and agriculture (Renwick et al., 2007) even though it has not been tested to determine the accuracy of the level of water access in different geographical locations (Kayser et al., 2013). Therefore, this is the reason for the selection of this indicator in the construction of the index for measurement of water access for livestock index in semi-arid areas in this study.

Quality
In this study quality dimension refers to acceptable user perception of water source services and this is determined according to local norms and standards (Moriarty, 2011). In Tanzania, context improved water sources are considered safe water as compared to unimproved water sources. Improved water sources and unimproved water sources were used as indicators for measuring water service quality (WHO-UNICEF, 2021). Improved water sources refer to public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs or rainwater collection whereas unimproved water sources refer to unprotected dug wells, unprotected springs, carts with small tanks, drums, surface water including river, dam, lake, pond, stream, canal, irrigation channels and bottled water.

Availability
Water availability refers to the existence of water for ecosystems and human societies to use (Feitelson, 2002). Water is available when those who wish to use it have access to it. Previous studies identified factors influencing household water accessibility as location, education, wealth, age, gender, ethnicity, electricity access, water collection time, and household size, (Abubakar, 2019; Simelane et al., 2020). In this study, two indicators were used to measure water availability specifically distance to water source walked by livestock and time spent per tropical livestock unit (per livestock) in watering. Tropical Livestock Unit (TLU) refers to livestock units owned by households (Begna and Masho, 2022).

Distance to water source walked by livestock
It was measured through distance in kilometers (km), walked by livestock from the homestead to the water source. During the dry season in Kenya, pastoralists had to walk 20 to 35 kilometers daily to bring their livestock to water sources and return home (OCHA, 2022; Mugambi et al., 2022). Furthermore, in Uganda it was revealed that during the dry season, pastoralists had to walk 6 to 23 km to access water (Egeru et al., 2022). Similarly, in Tanzania, it was noted that pastoralists in rural areas had to walk an average distance of nearly 7 km one way to access water for livestock and other uses from ponds and walked less distance an average of 4 km to access water from shallow wells (Ngasala et al., 2018). The distance to water source as a dimension was used because the distance walked by livestock in search of water reduces the household income of pastoralists (Hadush, 2018).

Time taken in watering livestock
This indicator in previous studies had different findings on time spent in fetching water from different water sources. Recent studies in Sub-Saharan Africa have reported that in rural areas, individuals used more than 30 minutes to access water (Terefe et al., 2024; Amankwaa et al., (2024); Baddianaah et al., 2024). In this study, time taken to drink water by livestock was taken to be on an average of 11.5 minutes per cattle as reported by Iteba et al. (2021). Howard and Bartram (2003) suggested an individual is considered having access to water if the total collection time ranges between 5 and 30 minutes.

Affordability
This dimension was measured through a single indicator, which is the threshold of household income used in water charges. Affordability refers to the burden experienced by household in terms of financial resources to access domestic water supply (Heyman et al., 2022). Likewise, UNDP insists that the water costs should not exceed 3% of the household income (Kayser, 2013). There is no universally agreed threshold used to measure the ratio of household income used to assess affordability. However, the recommendable threshold ranges from 3% to 5% as indicated in Table 1. These thresholds are grouped into two main categories those for water only and those for water services (Walsh et al., 2019).

Table 1: Thresholds applied by international agencies

International agency	Threshold (%)
UNDP (water only)	3
World Bank: Africa infrastructure (water services)	5
OECD (water only)	4
African Development Bank (water services)	5
Asian Development Bank (Water services)	5

Source: (Hutton, 2012; Smets, 2009; Masanyiwa et al., 2017)

Quantity
The quantity of water accessed by livestock in semi-arid is a social phenomenon that is difficult to measure using a single indicator. The quantity of water accessed by livestock was measured by using the proxy indicator of whether it was sufficient or insufficient. The quantity of water accessed by livestock in semi-arid range land is difficult to quantify because of the nature of water sources and infrastructures used by livestock and water availability.
It is possible to measure the level of water access by using the perception indicator as applied by Deal and Sabatini (2020) in measuring affordability and acceptability.

Table 2: Dimensions and Indicators of Water Access for Livestock Index

Dimensions	Indicators	Measurement
Availability	• Time per TLU • Distance to water source	• Minutes • Kilometre
Quantity	Perception of the quantity of water get livestock i.e. sufficient and not sufficient	1= Sufficient 0= not sufficient
Quality	Type of water sources i.e improved and unimproved water sources	1= improve water source 0= unimproved water source
Affordability	Percentage of income used for water charges (costs)	Tsh
Uses	Multiple uses	1= water source has multiple use 0=Has no multiple use

Note: Tropical Livestock Unit (TLU) refers to livestock units owned by households (Njuki, 2011), TLU for mature cow=1, sheep=0.20, oxen=1.42, donkey=0.80, heifer=0.78, poultry=0.04, bull=1.20 and calve=0.41, Tsh= Tanzania shilings

Conceptual framework of the study

The study's conceptual framework was based on the WHO-UNICEF JMP framework (2010) and the Multiple Use Services (MUS) framework by Renwick et al. (2007). The study also incorporated dimensions from various literature sources, particularly, proxy indicators such as the perception of the quantity of water accessed by households and affordability. These dimensions were used to establish the water access for livestock index. The study assumed that the six dimensions of water access for livestock were independent variables that had an influence on the level of water access for livestock, which is termed as the dependent variable. The independent variables included the distance to water source walked by livestock, time used in watering livestock, affordability, type of water source used by livestock (quality), multiple uses of water sources, and perception of the quantity of water drunk by livestock (Table 2). This approach has been proven to be useful in evaluating water supply services in both urban and rural areas (Antonio et al., 2022).

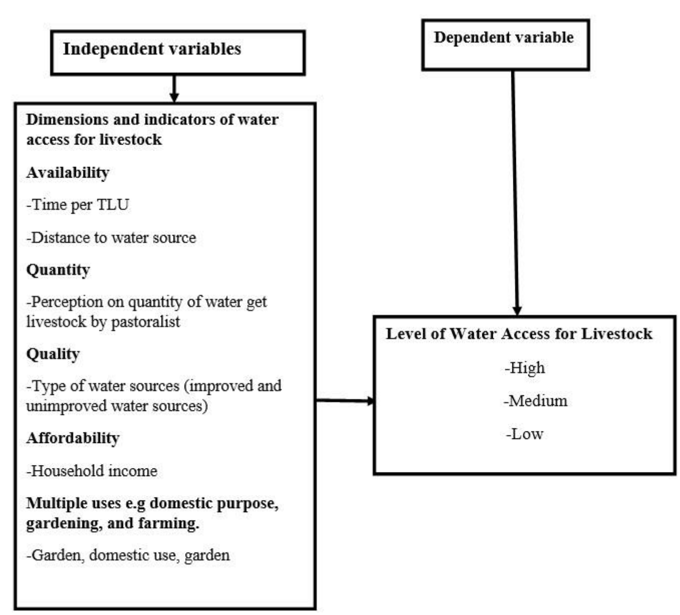

Figure 1: Conceptual framework of the study

Methodology

The study area

The study was conducted in the Monduli District in a lowland ecological zone, Arusha Region. The Monduli District is located between latitude 3 °15' and 3 °55′ South and between longitudes 35°55′ and 36°40′ East. It is bordered by the Kilimanjaro Region and Arumeru Districts to the East, Kenya to the North, Ngorongoro and Karatu Districts to the West, and Manyara Region to the South. Figure 2 presents a map of the Monduli District showing the location of the wards where the study was conducted. This area is characterized by 97% of individuals being pastoralists (Theodory and Malipula, 2014) and it experiences water scarcity for livestock (Msambichaka and Onyango, 2021; Chang'a and Kifaro, 2023) and has low rainfall ranging between 200mm to 600mm (Kimaro *et al*., 2018).

Research design, sampling procedure and sample size

The study used a cross-sectional research design, with the sampling frame being the list of all pastoralist households in the study area. The sampling unit was a household, and a multistage sampling technique was employed to obtain the sample. The first stage involved the purposive selection of Monduli District, followed by the selection of two wards in a lower ecological zone located in Moita and Makuyuni wards suitable for livestock activities. The next step involved purposively selecting seven villages, including three from Makuyuni and four from Moita. Finally, the head of each household was chosen by simple random sampling.

The sample size (N) of 367 was computed by using a Yamane (1967) formula. The population size (N) was 4390 households, and (e) the level of precision (sampling error) =5%. In addition, the stratified proportional formula by Salkind (2010) was used to calculate the sample size of each village (n_b).

$n_b = (N_h / N) * n$

Where n_b is the sample size for village (h), N_h is the population size for village (h), N is the total population size, and n is the total sample size. Then, the calculated sample sizes for Moita ward were 185 and Makuyuni 182 respectively.

Test of the instruments and data collection

The instrument's validity was ensured using two methods. First, the questionnaire was reviewed by professionals on water access and livelihood in semi-arid range lands. Second, the semi-structured questionnaire was distributed to more professionals to ensure accuracy and clarity. In addition, reliability refers to the consistency of results between different samples of the same population using the same methods. The study tested the reliability of research tools with 30 randomly selected respondents from Esilalei Village located in Esilalei ward. The data were analyzed using SPSS version 25, and the results showed a Cronbach's alpha coefficient of 0.81, indicating excellent reliability according to Hair et al. (2010).

The quantitative data was collected by using a household survey from 367 household survey respondents. The collected data were socio-economic characteristics namely age, sex, household size, education and marital status. The observation method was used to watch and take information about water sources, and the practice of watering of watering livestock at water points. Quantitative data was gathered through a household survey questionnaire answered by 367 respondents. The survey collected socio-economic information such as age, gender, household size, education level and marital status. The observation method was used to observe and record information about water sources and the practices of watering livestock at water points.

Data analysis

In the initial stage, descriptive statistics was used to analyze the quantitative data. This included examining frequencies and percentages related to demographics such as age, sex, household size, education, and marital status, as well as variables like the time taken to water livestock, distance travelled by livestock to water sources, type of water source, multiple uses of water sources, affordability, and perceived quantity of water accessed by households. Before running the model, the problem of multi-collinearity was examined through the use of Variance Inflation Factors (VIF).

Multinomial Logit Latent-Class Regression Models (MLLRM) were applied rather than the standard logit and probit models for several reasons to analyse pastoralist households' levels of water access for livestock. First, MLLRM are valuable for the identification of hidden differences in the relationships between predictor variables and a categorical dependent variable with more than two outcomes (Esmaili et al., 2023). Second, MLLRM detects distinct subgroups or "classes" within the data, where the relationships between the predictors and outcome variable differ across these unobserved classes (Hensher et al., 2015). Third, MLLRM models relax the assumption of Independence of Irrelevant Alternatives (IIA) in traditional multinomial logit models (Gupta and Porter, 2022). In our case, Hausman specification tests suggest a violation of the IIA assumption, and for that matter, the MLLRM models were preferred.

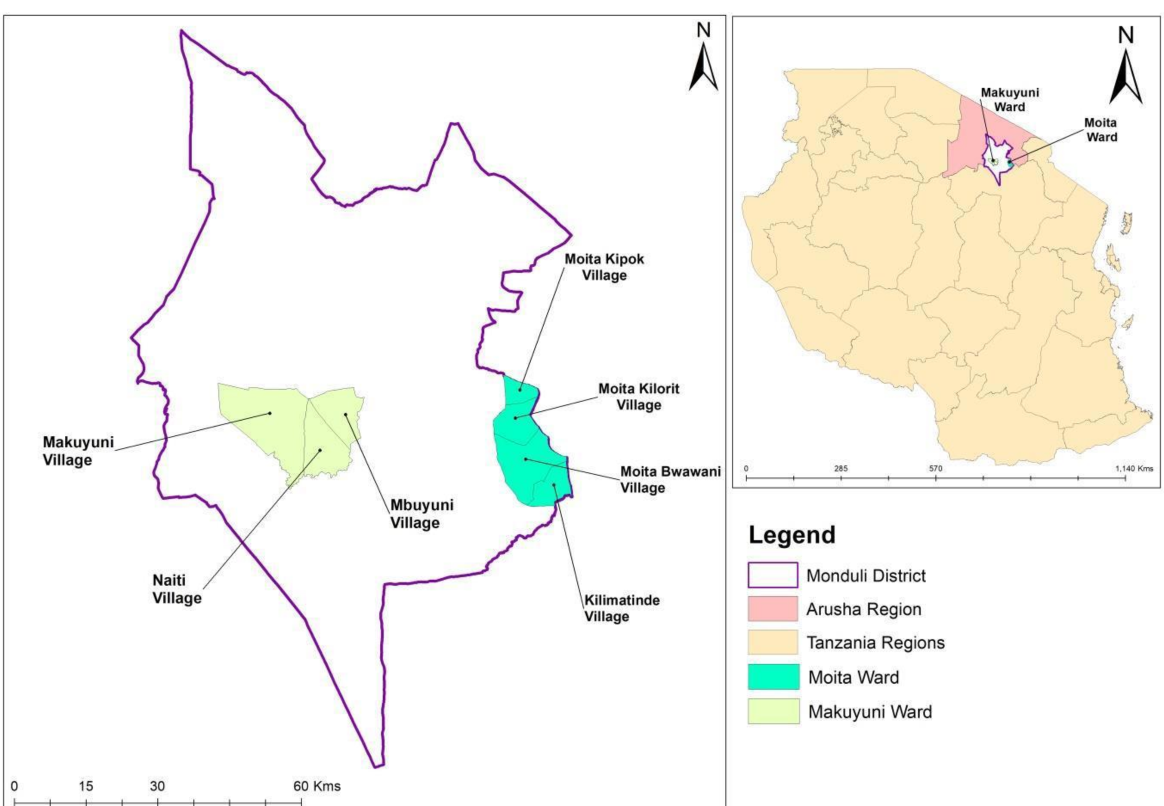

Figure 2: The study area

Three models were estimated and the best was selected based on the Bayesian Information Criterion the Akaike Information Criterion, and likelihood fit statistics. Equations 1 to 4 represent the Multinomial Logit Model used to determine the probability of each class regarding the base category. The dependent variable is the latent categorical variable water access (C) and the independent variables are the time taken to reach the water point by livestock (TL), distance (DS), type of water source (TW), affordability (AF), and multiple uses (MU).

$$Pr(C=1) = \frac{e^{\lambda 1}}{e^{\lambda 1}+e^{\lambda 2}+e^{\lambda 3}+e^{\lambda 4}} \quad \text{………… equation (1)}$$

$$Pr(C=2) = \frac{e^{\lambda 2}}{e^{\lambda 1}+e^{\lambda 2}+e^{\lambda 3}+e^{\lambda 4}} \quad \text{………………. equation (2)}$$

$$Pr(C=3) = \frac{e^{\lambda 3}}{e^{\lambda 1}+e^{\lambda 2}+e^{\lambda 3}+e^{\lambda 4}} \quad \text{………………...equation (3)}$$

$$Pr(C=4) = \frac{e^{\lambda 4}}{e^{\lambda 1}+e^{\lambda 2}+e^{\lambda 3}+e^{\lambda 4}} \quad \text{………………...equation (4)}$$

Where $\lambda 1, \lambda 2, \lambda 3$ and $\lambda 4$ are intercepts in the multinomial logit model. In our case, class 1 is a base category hence $\lambda 1 = 0$

Measurements of variables
Table 3 shows the dependent and independent variables that were used in the multinomial logit model.

Dependent variable	Variable definition and unit of measurement
Access to water (Y). for livestock =1 High accessible =Low	
Independent variable (x's)	
TL	Time used in watering livestock (minutes)
DIS	Distance walked by livestock to water point (1=≤10km 0=otherwise)
PC	Perception on quantity of water drink by livestock (1=sufficient 0=otherwise)
TW	The type of water source used (1=improved water source 0=otherwise)
AF	Affordability for water services (1=≤3% of household income used in water charges (costs) its affordable 0=otherwise
MU	Multiple uses of water sources (1= has multiple uses 0=otherwise

Methodology limitations
The study area was purposefully selected, and data were specifically gathered in the Monduli district in the semi-arid regions of Northern Tanzania. Tanzania has seven agro-ecological zones, including the coast, arid, semi-arid, plateau, southern and western highlands, and alluvial zones (Mkonda et al., 2018). However, it is important to note that, this study focused solely on one part of the semi-arid ecological zone. It is essential to interpret the results of this study with caution when considering the evaluation of water access for livestock in rangelands in other ecological zones. Furthermore, the findings are specific to the Monduli district council and may not be representative of other ecological zones in Tanzania.

Results and Discussion
Socio-economic characteristics and water access for livestock
The findings presented in Table 4 indicate that over 70 percent of respondents across various age groups, ranging from ≤36 to > 56, face limited water access for their livestock. Additionally, the chi-square analysis (df=4, $\chi 2$ =3.741, p=0.442) reveals that there is no significant variation in water access levels for livestock among different age categories of the respondents. This discovery suggests that a majority of respondents in the study area experienced water shortage for their livestock, irrespective of their age. Similarly, due to unaffordable water services, people walk long distances and spend over 5 hours securing water for themselves and their livestock. Households spend over 3% of their income on water access, leading to reliance on unimproved water sources such as dams and rivers. This finding contradicts the results of a study conducted by Balfour *et al*. (2022) in Kenya, which found that pastoralist households' women had to access water for their livestock and domestic use by paying and experienced long queues at water points. This study in Kenya also revealed women had to use up to one and a half hours compared to the youth because they were more experienced with different water use strategies for livestock.

The results in Table 4 show that 76.9% of male headed households had low access to water for livestock, compared to 25% of female-headed households. This means male pastoralists walk long distances to secure water for their livestock thus, spending more time (≥ 5 hours), more money (≥ 3% of household income) and using more improved water sources than female headed households. This finding is contrary to that of Nordström and Widman (2022) and Shah et al. (2023) conducted in low and middle -income countries, which revealed that women had a burden to access water as compared to men and needed to walk long distances to fetch water for domestic purpose. The findings are further supported by Chi-square results ($\chi 2$ =6.990, df=2, p=0.030), indicating a significant difference between the sex of respondents and the level of water access for livestock. This finding is consistent with previous studies by Ngarava et al. (2019) in Ghana, which found that female headed households generally have better access to improved water sources than male headed households.

Likewise, Table 4 shows that over 65% of households have limited access to water for their livestock. The Chi-square analysis ($\chi 2$ =2.999, df=4, p=0.558), indicates no correlation between household size and water access for livestock. This is consistent with the findings of Abubakar (2019), who explored the same theme in Nigeria. Similarly, Dungumaro (2007) contends that the larger the household, the more income is spread and the higher poverty levels which eventually leads to the use of unimproved water sources (low water access). In addition, the results in Table 4 show that over 75% of respondents had limited water access for livestock, regardless of their education level. Chi-square results ($\chi 2$= 2.185, df=4, p=0.702) indicate no significant difference between respondent's education level and access to water for livestock. This finding is consistent with Balfour et al. (2020) who found no significant difference between education levels of the heads of households and water security.

Lastly, the results in Table 4 show that over 70% of both polygamous and monogamous household heads have limited access to water for livestock. Additionally, 50% of single household heads also have limited access to water for livestock. This finding indicates that marital status does not significantly affect water access for livestock as shown by the Chi-square results ($\chi 2$= 3.325, df=4, p=0.505). These results differ from a previous study by Amankwaa *et al*. (2024) in Ghana which revealed that household with married heads had limited water access as compared to those who have never married.

The level of water access for livestock by pastoralist households
On the average, the proportion of respondents who reported having access to water for livestock ranges from 39% improved water sources to 65% multiple uses of water as depicted in Table 5. However, there are significant differences between wards. For instance, while 51% of all individuals reported having a short distance to the water source (less than 10 km), Makuyuni ward had about 86% while Moita is only 17%. The difference is 70% and is statistically significant (p < 0.01). Overall, Makuyuni ward pastoralist households had higher water access for livestock as compared to Moita in regard to the indicator variables (Table 5). This situation was caused by the existence of reliable water sources both improved water sources especially boreholes and unimproved water sources like the Naiti earth dam in Makuyuni ward as compared to the Moita ward which has no reliable water sources due to the destruction of the Moita earth dam by floods and the problem of frequently breakdown of the MONALO water projects. This situation caused Moita people to experience more shortage of water in all variables except in multiple uses only 65% (Table 5). This study is contrary to that of Deal and Sabatini (2020) on the evaluation of the level of the water service provided by private water enterprises in Ghana. They used 13 indicators for measuring the level of water service but none of the indicators were applied to measure water access for livestock. Furthermore, they measured the affordability of water service in terms of perception rather than a portion of household income used in water costs.

Table 4: Socio-demographic characteristics and water access for livestock (n=367)

Variable		Level of water access for livestock						Chi-square		
		Low		Medium		High				
Age	n_o	n_L	%	n_M	%	n_H	%	d	χ2	p-value
≤36	40	35	87.5	5	12.5	0	0			
36-56	231	172	74.5	52	22.5	7	3			
>56	96	73	76	21	21.9	2	2.1			
Sex										
Male	363	279	76.9	75	20.7	9	2.5	2	6.990	0.030*
Female	4	1	25	3	75	0	0			
Household size										
1-3	14	11	78.6	3	21.4	0	0			
4-6	71	49	69	20	28.2	2	2.8	4	2.999	0.558
>7	228	220	78	55	19.5	7	2.5			
Education										
Never attended school	169	128	75.7	35	20.7	6	3.6			
Primary education and above	198	152	76.8	43	21.7	3	1.5	2	2.185	0.702
Marital status										
Monogamous	170	126	74.1	40	23.5	4	2.4			
Polygamous	193	152	78.8	36	18.7	5	2.6	4	3.325	0.505
Single	4	2	50	2	50	0	0			

Note: no = overall number/frequency, nL, nM and nH= Frequency for low, medium and high water access, * indicates significance at 5 per cent

Table5:Distributionofpastoralists'households'wateraccessforlivestockuse

Variables	Makuyuni	Moita	Average Total	Mean Difference
Short distance walked by livestock to water point	0.863	0.168	0.512	0.70***
	(0.345)	(0.374)	(0.501)	[0.04]
Less time used to drink water by livestock	0.736	0.319	0.526	0.42***
	(0.442)	(0.467)	(0.500)	[0.05]
Sufficient water supply to livestock	0.934	0.157	0.542	0.78***
	(0.249)	(0.365)	(0.499)	[0.03]
Affordable water by household	0.489	0.341	0.414	0.15***
	(0.501)	(0.475)	(0.493)	[0.05]
Improved source used by livestock	0.401	0.384	0.392	0.02
	(0.491)	(0.488)	(0.489)	[0.05]
Multiple uses of water	0.538	0.751	0.646	-0.21***
	(0.500)	(0.433)	(0.479)	[0.05]
N	**367**			

Note: PARATHESIS indicate standard deviation, [ ] =Standard Error (SE), *** and indicates significance at 1% and figures without brackets are proportions (%).

Table 6: The specific logistic regression models for water access for livestock indicators

Variables	Models			
	Class 1	Class 2	Class 3	Class 4
Short distance	-4.29**	-1.92***	1.30***	2.37***
	(1.77)	(0.67)	(0.34)	(0.73)
less time	-2.06***	-0.61**	1.66***	0.59**
	(0.47)	(0.24)	(0.40)	(0.29)
Sufficient water	-2.45***	-2.40***	4.04***	1.74***
	(0.62)	(0.74)	(1.41)	(0.56)
Affordability	-2.28***	-0.26	-1.24**	1.03**
	(0.58)	(0.22)	(0.51)	(0.46)
Improved source	13.86	-2.34***	0.59	-1.93***
	(417.69)	(0.89)	(0.44)	(0.55)
Multiple uses	2.60***	0.26	-0.83*	1.84**
	(0.80)	(0.25)	(0.43)	(0.73)

Note: *** and * and ** indicate significance levels at 1%, 5% and 10% .

Multinomial logistic regression analysis results

The findings show that the model categorized pastoralist households into four classes of water access for livestock. It was observed that Class 1 (Table 6) has a negative relationship with short distance, less time, sufficiency of water and affordability, and a positive relationship with improved water source and multiple uses. Class two has a negative relation with all variables, except for multiple uses. On the other hand, Class 3 and Class 4 have a positive relation with all variables except affordability and multiple uses for class 3 and improved sources for class 4 (Table 6). This finding implies that, in the study area, there were four categories of pastoralist households with different levels of water access, but none of the single categories of the population has attained an optimal level of all indicators for measuring water access for livestock in the study area. This implies that, it is difficult to find pastoralist households in semi-arid areas in the study area with optimal levels of water access according to the established index for measuring water access for livestock. This finding is inconsistent with that of Deal and Sabatini (2020) conducted in Ghana on the evaluation of the household level of water services, which used thirteen indicators to measure the level of use of domestic water services, but none of the indicators measured water access for the livestock. Furthermore, the study by Deal and Sabatini (2020) established that households were not able to water service despite using multiple water sources.

Proportions of the pastoralist households and level of water access for livestock

We can understand and interpret these classes by investigating the marginal probabilities and marginal means of the variables. Marginal probabilities present the expected proportions of the population in each group, while marginal means give the conditional probability of each variable to the classes and foster meaning to the groups of each variable of the class groups (Figure 3) and also the marginal probabilities of each group. Based on this model, the study estimated that 16.4% of the population is in class 1, 28.1% is in class 2, 25.8% is in class 3 and 29.7% are in class 4 (Table 7). We can clearly understand what these classes represent by looking at Figure 3. Starting class 4 indicates (29.7% of the population) see Table 7, the probabilities of positive values are high for all variables, except for improved water sources (Figure 3). This group has people with high access to water with poor quality *"High access-low quality."* Class 3 has fairly high values for all variables except for affordability and multiple uses. We can label this group (Figure 3) as *High access-low affordability and uses management"*. Class 1 has fairly low values for all variables except for improved sources and multiple uses. We label this group as *low access-high quality*. The last group is class two with low values for almost all values hence we label it as a *Low access group* (Figure 3).

Table 7: Proportions of water access for livestock and population groups in the study area

Classes	Margin	Std. Err.	[95% Conf.Interval]	
Class 1	0.164064	0.027036	0.117672	0.2241
Class 2	0.281206	0.045367	0.201267	0.377875
Class 3	0.257997	0.063203	0.15401	0.399075
Class 4	0.296733	0.074133	0.173766	0.458437

This finding differs from that of Castillo et al. (2024), who conducted research in the semi-arid areas of Northern Chile which established the Access to Rural Drinking Water and Sanitation Services Index (ARDWSVI). This finding did not focus on water accessibility for livestock but rather, concentrated on domestic purposes especially drinking water and sanitation services in rural semi-arid areas. This index used sixty-five (65) indicators with three dimensions namely social, economic and environmental to account for the vulnerability in access to drinking water and sanitation services in semi-arid areas of Northern Chile. This index established five categories of levels of water access including very high vulnerability (80<ARDWSVI ≤100), high vulnerability (60<ARDWSVI ≤80), medium (40<ARDWSVI ≤ 60), low (20<ARDWSVI ≤ 40) and very low vulnerability (0<ARDWSVI ≤ 20).

Predicted group categories of water access for livestock by pastoralists

The study findings revealed that Makuyuni pastoralist households had the highest level of water access for livestock, with 48.4% having high access to water, although of low quality (Figure 4). This implies that unimproved water sources, such as unprotected water sources like dams, were preferred over improved water sources. In the Moita ward, 47% of pastoralist households had low access to water for livestock with multiple uses, indicating that those with water access used it for other activities such as domestic use, gardening, and brick making (Figure 4). Despite Moita ward having lower water access compared to Makuyuni ward, the results indicated that 34.6% of pastoralist households used tap water (an improved water source) for their livestock. In terms of affordability, the study indicated that only 3.8% of pastoralist households in the Moita ward afforded water charges for livestock compared to 45.6 % Makuyuni pastoralist households (Figure 4). This implies that few pastoralists were capable of financing improved water for their livestock. The price for watering livestock from improved water sources (tap water, boreholes) was high, ranging from TShs 10 to TShs 50 per sheep or goat, and TShs 50 to 100 per cattle or donkey. Similar findings by Dika et al. (2023) in Ethiopia revealed low water insecurity among Borana pastoralists. This similar finding was attributed to the context of the historic challenge of water shortage for livestock by pastoralists in semi-arid areas of East African rangelands and other semi-arid areas of Sub-Saharan Africa.

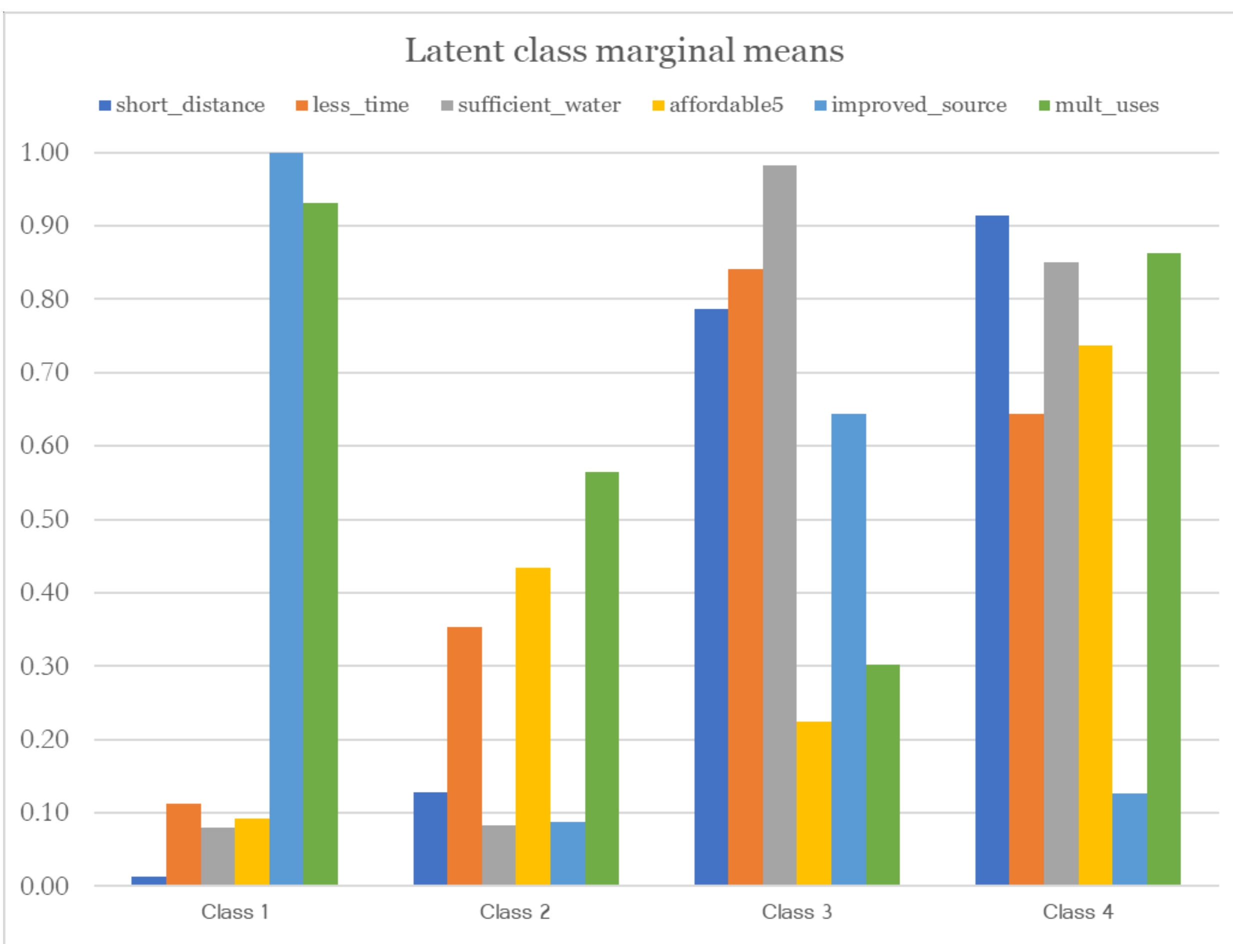

Figure 3: Level of water access for livestock per category (class) in the study area

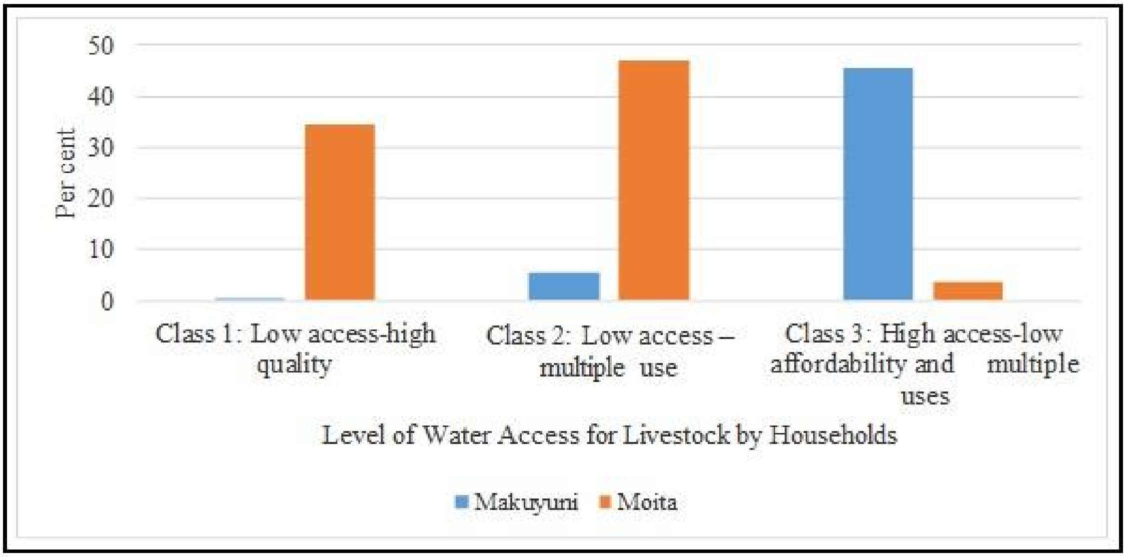

Figure 4: Categories of water access for livestock by pastoralist households

Conclusion and Recommendations

The study concludes that pastoralists had limited access to water due to the reliance on unimproved sources, leading to utilization of poor-quality water. In addition, the use of improved water sources for livestock is expensive and vice versa. Moreover, household income (affordability) is the determinant of the levels of water access for livestock and last but not least, few pastoralist households had managed to access quality water (improved water sources) for livestock in the study area. The study recommends the following: Pastoralist communities could improve livestock water access through financial support from banks and cost-sharing for constructing improved and unimproved water sources such as charco dams and boreholes. This can be achieved through the adoption of models of community-based water point management that support fair water access while assisting in reducing water costs. In addition, investments from the Local Government Authority Monduli District and Non-Governmental Organizations should be directed towards enhancing water sources closest to pastoralist communities and transhumance routes, rather than farther away. Furthermore, Monduli District Council, in collaboration with livestock stakeholders such as the Ministry of Agriculture, Ministry of Livestock and Fisheries and private sectors should support pastoralists in diversifying income sources by engaging in drought-resistant crop production and small businesses to increase their ability to afford water charges for their livestock and other uses.

Further research

The conclusions of this work lay the groundwork for further investigation into livestock access to water in semi-arid rangelands. Future research could focus on evaluating the success of interventions meant to enhance livestock water access in the study area.

Acknowledgement

The researchers thank the Institute of Rural Development Planning for letting them do the study. They are also grateful to the people in the Monduli District for sharing their local knowledge during the research.

Conflicts of Interests

The authors declare that they have no conflicts of interest.

Reference

Abubakar, I. R. (2019). Factors influencing household access to drinking water in Nigeria, *Utilities Policy*, 58, 40-51. https://doi.org/10.1016/j.jup.2019.03.005

Alemayehu, M. A., Agimas, M. C., Shewaye, D. A., Derseh, N. M., & Aragaw, F. M. (2023). Spatial distribution and determinants of limited access to improved drinking water service among households in Ethiopia based on the 2019 Ethiopian Mini Demographic and Health Survey: spatial and multilevel analyses. *Frontiers in Water* 5:1-14. https://doi.org/10.3389/frwa.2023.1166733

Amankwaa, G., Busia, K. A., Agbadi, P., Duah, H. O. & Holmes, F. A. (2024). Access heterogeneities and collection time inequalities of drinking water sources in Ghana: implications for water and development policy. *Local Environment*, 29 (3), 263-278. https://doi.org/10.1080/13549839.2024.2306596

Amole, T. A., Adekeye, A. & Ayantunde, A. A. (2021). Assessment of Livestock Water Productivity in Seno and Yatenga Provinces of Burkina Faso. *Frontiers in Sustainable Food System* 5, 1-14. https://doi.org/10.3389/fsufs.2021.632624

Antonio, P. G. L., Vicent, A. L. & Ramón, F. P. (2022). A composite indicator index as a proxy for measuring the quality of water supply as perceived by users for urban water services. *Technological Forecasting and Social Change*, 174, 1-16. https://doi:10.1016/j.techfore.2021.121300

Assefa, Y. T., Babel, M.S., Sušnik, J. &Victor R. Shinde, (2018). Development of a Generic Domestic Water Security Index, and Its Application in Addis Ababa, Ethiopia. *Water*, 11 (37), 1-23. https://doi.org/10.3390/w11010037

Baddianaah, I., Dongzagla, A. & Salifu, S. N. (2024). Navigating access to safe water by rural households in sub-Saharan Africa: Insights from north-western Ghana. *Sustainable Environment*, 10 (1), 1-15. https://doi:10.1080/27658511.2024.2303803

Balfour, N., Obando, J. & Gohil, D. (2020). Dimensions of water insecurity in pastoralist households in Kenya. *Waterlines*, 39 (1), 24−43. https://doi:10.3362/1756-3488.19-00016

Begna, R. & Masho, W. (2024). Valuation of livestock population and national feed security to enhance livestock productivity in Ethiopia. *Ruminants*, 10, 1-24. https://doi: 10.1002/vms3.141

Bogale., G. A. & Erena, Z. B. (2022). Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-ecological zones of Ethiopia, *Journal of Applied Animal Research*, 50 (1), 471-489.

Bolaane, B., Tema, N., & Phuthologo, B. (2021). Barriers and coping strategies of households with no access to drinking water and waterborne sanitation in two low-income neighbourhoods in Botswana. Habitat International, 115, 1-8. https://doi:10.1016/j.habitatint.2021.102372

Bosire, C. K., Mtimet, N., Enahoro, D., Ogutu, J. O., Krol, M. S., de Leeuw, J., Ndiwa, N. & Hoekstra, A. Y. (2022). Livestock water and land productivity in Kenya and their implications for future resource use. *Heliyon*, 8(3), 1-13. https://doi.org/10.1016/j.heliyon.2022.e09006

Boyomo, H.A. A., Nkoa, B.E. O. & Manga, L. A. A (2024). Climate change and livestock production in Sub-Saharan Africa: Effects and transmission channels. *Food and Energy Security*, 13, 1-21. https://doi.org/10.1002/fes3.521

Campos, L. C., Olago, D. & Osborn, D. (2022). Water and the UN sustainable development goals. *UCL Open: Environment*, 4, 1-2. https://doi.org/10.14324/111.444/ucloe.000029

Cassivi, A. Dorea, C. C. Johnston, R. & Waygood, E. O. D. (2018). Access to drinking water: Time matters. *Journal of Water and Health*, *16*(4), 661–666. https://doi.org/10.2166/wh.2018.009

Castillo, C. V., Cobo, J. N., Escobara, G. M. & Bravo, S. S. (2024). Development and assessment of a vulnerability index for access to rural drinking water and sanitation services in the semi-arid region of north–central Chile. *Journal of Water, Sanitation and Hygiene for Development,* (1), 1-16. https://doi.org/10.2166/washdev.2024.106

Chang'a, E. P. & Kifaro, G. C. (2023). Husbandry and Productivity of Red Maasai Sheep in Arumeru and Monduli Districts in Tanzania. *European Journal of Agriculture and Food Sciences,* 5 (5), 16-23. https:// doi: 10.24018/ejfood.2023.5.5.717

Clark, V. L. P. & Ivankova, T. (2016). Mixed Method Research: A Guide to the field. Thousand Oaks, CA: Sage Publications.

Daly, S., Lowe, J., Hornsby, G. & Harris, A. (2024). Multiple water source use in low- and middle-income countries: a systematic review. *Journal of Water and Health*, 19 (3), 370–392. https://doi.org/10.2166/wh.2021.205

Deal, P. & Sabatini, D. (2020). Evaluating the Level of the Household Water Service Provided by a Private Water Enterprise in Ghana. *Water*, 12 (693), 1-18. https://doi.org/10.3390/w12030693

Dika, G., Tolossa, D., & Eyana, S. M. (2023). Understanding Poverty and Survival Strategy among Ethiopian Pastoralists: The Boorana Pastoralists Perspectives. *International Journal of Rural Management*, 19(2), 171-188.

Drastig, K., Vellenga, L., Qualitz, G., Singh, R., Pfister, S., Boulay, A. M., Wiedemann, S., Prochnow, A., Chapagain, A., De Camillis, C., Opio, C. & Mottet, A. (2021). Accounting for livestock water productivity - How and why? Land and Water Discussion Papers. Rome, FAO.

Duale, M.M. (2024). Resilience and Transformation: Examining Pastoral Development Initiatives in Ethiopia—Article Review. *Open Access Library Journal,* 11, 1-18.

Eeswaran, R., Nejadhashemi, A.P., Faye, A., Min, D., Prasad, P.V.V., & Ciampitti, I.A. (2022). Current and Future Challenges and Opportunities for Livestock Farming in West Africa: Perspectives from the Case of Senegal. *Agronomy*, 12 (1818), 1-23. https://doi.org/10.3390/agronomy12081818

Egeru, A., Mensah, S., Kuule, D.A., Siya, A. & Asiimwe, R. (2022). Analysis of Adaptation Diversity to Climate Variability and Change among Pastoral Communities in North-Eastern Uganda. *African Crop Science Journal*, 30, (s1), 141 – 170.

Esmaili, A., Aghabayk, K., & Shiwakoti, N. (2023). Latent Class Cluster Analysis and Mixed Logit Model to Investigate Pedestrian Crash Injury Severity. *Sustainability,* 15 (185), 1-29. https://doi.org/10.3390/su15010185

FAO, Food and Agriculture Organization of the United Nations (2022). Impacts of Drought on Livestock and Pastoralists in East Africa.

Feitelson, E. & Chenoweth, J. (2002). Water poverty: Towards a meaningful indicator. *Water Policy*, 4 (3), 263–281. https://doi.org/10.1016/S1366-7017 (02)00029-6

Gupta, H. & Porter, M. A. (2022). Mixed Logit Models and Network Formation. *Journal of Complex Networks,* 10 (6), 1-34. https://doi:10.1093/comnet/cnac045

Hadush, M. (2018). Welfare and Food Security Response of Animal Feed and Water Resource Scarcity in Northern Ethiopia. *Agricultural and Food Economics,* 6(22), 1-24. https://doi.org/10.1186/s40100-018-0116-2

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate Data Analysis (7th ed.). Pearson Prentice-Hall, New Jersey.

Hamilton, S. H., Merritt, W. S., Das, M., Rahman, M. W., Bhuiya, S. S., Carter, L., Cosijn, M. Roth, C. H. Singha, S. & Syme, G. J. (2020). Integrated assessment—how does it help unpack water access by marginalized farmers? *Water (Switzerland)*, *12*(12), 1–22. https://doi.org/10.3390/w12123444

Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). Applied choice analysis (Second Edition). Cambridge University Press.

Heyman, J. M., Mayer, A. & Alger, J. (2022). Predictions of household water affordability under conditions of climate change, demographic growth, and fresh groundwater depletion in a southwest US city indicate increasing burdens on the poor. *PLoS One, 17*(11), 1-23. https://doi.org/10.1371/journal.pone.0277268.

Howard, G. & Bartram, J. (2003). *Domestic Water Quantity, Service Level and Health*; World Health Organization: Geneva, Switzerland.33pp.

Iteba, J. O., Hein, T., Singer, G. A. & Masese, F. O. (2021). Livestock as vectors of organic matter and nutrient loading in aquatic ecosystems in African savannas. *PloS one, 16*(9), 1-24. https://doi: 10.1371/journal.pone.0257076.

Jensen, H. M., Villumsen, M. & Petersen, T. D (2014). The AAAQ Framework and The Right to Water International indicators for availability, accessibility, acceptability and quality. An Issue Paper of the AAAQ toolbox.

Jepson, W., Stellbauer, M. & Thomson, P. (2023). Revaluing multiple-use water services for food and water security. FAO Land and Water Discussion Paper No. 19. Rome, FAO.

Johnson, L., Mohamed, T. S., Scoones, I. & Tave, M. (2023). Uncertainty in the drylands: Rethinking in/formal insurance from pastoral East Africa. Environment and Planning A: *Economy and Space, 55*(8), 1928–1950. https://doi.org/10.1177/0308518X23116.

Joseph, L. and Kaswamila, A. (2017). The Pastoralists' Resilience and Innovative Adaptation Strategies on Impacts of Climate Change in Rangelands of Longido District, Tanzania. *International Journal of Environment and Bioenergy,* 2(1), 47-61.

Joseph, L. S. (2022). Factors that Accelerate Vulnerability to Climate Change Impact among the Agro- Pastoralists in Arumeru. Tanzania. *East African Journal of Education and Social Sciences 3*(2), 37-47. https:// doi:10.46606/eajess2022v03i02.0157

Kariuki, J., Yameogo, V., Daum, T., Birner, R., & Chagunda, M. (2022). Do African livestock policies address sustainability trade-offs? Evidence from Kenya, Zambia, and Burkina Faso. Hohenheim Working Papers on Social and Institutional Change in Agricultural Development. University of Hohenheim.

Kashem, S., Tahsin, N., Subah, Z., Murshed, S. B., Nowreen, S. & Mondal, M.S. (2023). Assessing the right to water of the urban poor in Dhaka city. *GeoJournal, 88* (3), 183–3204. https://doi.org/10.1007/s10708-022-10804-3

Kayser, G.L. Moriarty, P., Fonseca, C. & Bartram, J. (2013). Domestic Water Service Delivery Indicators and Frameworks for Monitoring, Evaluation, Policy and Planning: *A Review, International Journal of Environmental Research and Public Health,* 10, 4812-4835.

Kimaro, E. G., Mor, S. M., & Toribio, J. A. L. M. L. (2018). Climate Change Perception and Impacts on Cattle Production in Pastoral Communities of Northern Tanzania. *Pastoralism,* 8(1), 1–16. https://doi.org/10.1186/s13570-018-0125-5

Magnusson, U., Boqvist, S., Doyle, R., & Robinson, T. (2022). *Animal health and welfare for sustainable livestock systems*. Global Agenda for Sustainable Livestock, Rome.

Mahoo, H. Simukanga, L. & Kashaga, R. (2015). Water Resources Management in Tanzania: Identifying Research Gaps and Needs and Recommendations for a Research Agenda. *Tanzania Journal of Agricultural Sciences, 14*(1), 57–77.

Majuru, B., Suhrcke, M. & Hunter, P. R. (2018). Reliability of water supplies in low and middle-income countries: A structured review of definitions and assessment criteria. *Journal of Water Sanitation and Hygiene for Development*, *8*(2), 142–164. https://doi.org/10.2166/washdev.2018.174

Mapfumo, L., Muchenje, V., Mupangwa, J. F., Scholtz, M. M., & Washaya, S. (2021). Dynamics and influence of environmental components on greenhouse gas emissions in sub-Saharan African rangelands: A review. *Animal Production Science, 61* (8), 721–730. https://doi.org/10.1071/AN20564

Masanyiwa, Z. S. Kilobe, B. M. & Mbasa, B. N. (2017). Household Access and Affordability to Pay for Domestic Water Supply Services in Small Towns in Tanzania: A Case of Selected Towns along the Shores of Lake Victoria, *International Journal of Applied and Pure Science and Agriculture*, *3* (4): 46-58.

Mati, B. M., Muchiri, J. M., Njenga, K., Penning de Vries, F. & Merrey, D. J. (2005). *Assessing water availability under pastoral livestock systems in drought-prone Isiolo District, Kenya.* Working Paper 106. Colombo, Sri Lanka: International Water Management Institute (IWMI).

McGahey, D., Davies, J., Hagelberg, N., & Ouedraogo, R., (2014). Pastoralism and the Green Economy – a natural nexus? Nairobi: IUCN and UNEP.

Mfinanga, F. A., Msuya-Bengesi, C. P. & Madaha, R. M. (2023). Water Use Strategies for Livestock by Pastoralists: The Case of Semi-Arid Areas in Monduli District, Arusha Region, Tanzania *African Journal of Climate Change and Resource Sustainability*, *2*(1),1-12. https://doi.org/10.37284/ajccrs.2.1.1085

Mkonda, M. Y., He, X. H., & Festin, E. S. (2018). Comparing smallholder farmers' perception of climate change with meteorological data: experiences from seven agro-ecological zones of Tanzania. *Weather Climate and Society, 10* (3), 435–452.

Mohamed, A.A (2019). Pastoralism and Development Policy in Ethiopia: A Review Study. *Budapest International Research and Critics Institute Journal, 2* (4), 1-12.

Moriarty, P., Batchelor, C., Fonseca, C., Klutse, A., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, V. R. & Snehalatha, M. (2011). Ladders for assessing and costing water service delivery. In WASHCost Working Paper 2 (No. 2; WASHCost Working Paper 2, Issue November).

Msambichaka, S. J. & Onyango, P. O. (2021). Assessment of the Effect of Pastoral Mobility on Food Security in Semi-Arid Areas of Simanjiro and Handeni Districts, Tanzania. *Journal of the Geographical Association of Tanzania,* 41 (1), 133–149. https://doi.org/10.56279/jgat.v41i1.11

Mugambi, C., Osodo, P., Kithinji, C., Kanyuuru, C., Kinusu., K. & Kimiti, D. (2022). Baseline Evaluation for the Resilient Arid Lands Partnership for Integrated Development Plus (Rapid+) Program. Final Report. Millennium Water Alliance, Kenya Program.

Nejadhashemi, A.P., Faye, A., Min, D., Prasad, P.V.V., & Ciampitti, I.A. (2022). Current and Future Challenges and Opportunities for Livestock Farming in West Africa: Perspectives from the Case of Senegal. *Agronomy, 12,* (1818), 1-23. https://doi.org/10.3390/agronomy12081818

Ngasala, T. M., Masten, S. J., Phanikumar, M. S. & Mwita, E. J. (2018). Analysis of water security and source preferences in rural Tanzania. *Journal of Water, Sanitation and Hygiene for Development, 8* (3), 339-448. https://doi.org/10.2166/washdev.2018.169

Niyonzima, T. Stage, J. & Uwera, C. (2013). The Value of Access to Water: Livestock Farming in the Nyagatare District, Rwanda. *Springer Plus, 2* (644), 1-6. https://doi.org/10.1186/2193-1801-2-644

Njuki, J., Poole, J., Johnson, N., Baltenweck, I., Pali, P., Lokman, Z., & Mburu, S. (2011). Gender, Livestock and Livelihood Indicators. International Livestock Research Institute, Nairobi.

Nordström, M. & Widman, I. (2023). "Until I see that I have water, I am never free": Gendered experiences of water scarcity. Unpublished Bachelor Degree Thesis, Södertörn University.

Nounkeu, C. D., Metapi, Y. D., Ouabo, F. K., Kamguem, A. S. T., Nono, B., Azza, N, (2022). Leumeni, P., Nguefack-Tsague. G., Todem. D., Dharod, J. M., & Kuate, D. Assessment of drinking water access and household water insecurity: A cross-sectional study in three rural communities of the Menoua division, West Cameroon. *PLOS Water,* 1(8), 1-15. https://doi.org/10.1371/journal.pwat.0000029

OCHA, (2022). Kenya Drought Flash Appeal: October 2021-October 2022. Retrieved from https://reliefwebint/report/kenya/kenya-drought-flash-appealoctober- 2021-october-2022-revised-may-2022

Ocholla, G., Letema, S., & Mirer, C. (2022). Socioeconomic determinants of water delivery satisfaction in a medium sub-Saharan Africa city: A case of Kisumu, Kenya. *Water Supply 22* (12), 8683-8697. https://doi.org/10.2166/ws.2022.388

Oskam, M. J., Pavlova, M., Hongoro, C. & Groot, W. (2021). Socio-Economic Inequalities in Access to Drinking Water among Inhabitants of Informal Settlements in South Africa. *International Journal of Environmental Research and Public Health,* 18(19), 1-19. https://doi: 10.3390/ijerph181910528

Piemontese, L., Terzi, S., Di Baldassarre, G. Schwieger, D. A. M., Castelli, G. & Bresci, E. (2024). Over-reliance on water infrastructure can hinder climate resilience in pastoral drylands. *Nature. Climate Change, 14,* 267–274. https://doi.org/10.1038/s41558-024-01929-z

Rakotomanana, H., Komakech, J. J., Walters, C. N., & Stoecker, B. J. (2020). The WHO and UNICEF Joint Monitoring Programme (JMP) Indicators for Water Supply, Sanitation and Hygiene and Their Association with Linear Growth in Children 6 to 23 Months in East Africa. *International Journal of Environmental Research and Public Health. 17 (6262), 1-14.* https:// doi: 10.3390/ijerph17176262.

Renwick, M. Joshi, D. Huang, M. Kong, S. Petova, S. Bennett, G. Bingham, R. Fonseca, C.Moriarty, P. & Smits, S. (2007). Multiple-Use Water Services for the Poor: Assessing the State of Knowledge. Winrock International: Arlington, VA, USA.

Reynaert, E., Hess, A. & Morgenroth, E. (2021). Making Waves: Why water reuse frameworks need to co-evolve with emerging small-scale technologies. *Water Research X,* 10 0 094, 1-5. https://doi: 10.1016/j.wroa.2021.100094

Salkind, N. J. (2010). Encyclopedia of Research Design. Retrieved from [https://methods.sagepub.com/Reference/encyc-of-research-design 20/07/2021] Site visited on 20/11/2023.

Sesabo, J. K. (2024). Understanding the Impact of Water Accessibility and Sanitation-Related Diseases on Livelihoods in Tanzania. *African Journal of Empirical Research,* 4 (2):231-240. https://doi.org/10.51867/ajernet.5.1.23

Shah, S. H., Harris, L. M., Menghwani, V., Stoler, J., Brewis, A., Miller, J. D., Workman, C. L., Adams, E. A., Pearson, A. L., Hagaman, A., Wutich, A., & Young, S. L. (2023). Variations in household water affordability and water insecurity: An intersectional perspective from 18 low- and middle-income countries. Environment and Planning F, 2(3), 369-398. https://doi.org/10.1177/26349825231156900

Shrivastava, P. & Mategaonkar, M. (2024). Case study on water quality index for wastewater treatment in Mumbai. *Water Practice & Technology,* 19 (4), 1177-1184. https://doi.org/10.2166/wpt.2024.081

Simelane, M. S., Shongwe, M. C., Vermaak, K. & Zwane, E. (2020). Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. *Advances in Public Health,* (6758513), 1-9. https://doi.org/10.1155/2020/6758513

Smets H. (2009). Access to drinking water at an affordable price in developing countries. Options Mediterraneennes, A n 88, 57-68.

Terefe, B., Jembere., M. M. & Assimamaw, N. T. (2024). Access to drinking safe water and its associated factors among households in East Africa: a mixed effect analysis using 12 East African countries recent national health survey. *Journal of Health, Population and Nutrition, 43* (72), 1-10. https://doi.org/10.1186/s41043-024-00562-y

Theodory, T.F., & Malipula, M. (2014). Climate change and socio-economic vulnerability among Maasai pastoral communities in Northern Tanzania. *Journal of Policy and Leadership 2,* 1–19.

Tugjamba, N., Greg Walkerden, G., & Fiona Miller, F. (2023). Adapting nomadic pastoralism to climate change. *Climatic Change, 176* (28), 1-20. https://doi.org/10.1007/s10584-023-03509-0

Tulu, D., Hundessa, F., Gadissa, S. &Temesgen, T. (2024) Review on the influence of water quality on livestock production in the era of climate change: perspectives from dryland regions, *Cogent Food and Agriculture, 10* (1), 1-15. https://doi.org/10.1080/23311932.2024.2306726

UNICEF/WHO (2015). The most recent JMP report: Progress on sanitation and drinking water 2015 update and MDG assessment. New York.

Van Koppen, B., Moriarty, P., Boelee, E., & Hagmann, J. (2006). *Multiple Use Water Services to enhance the Millennium Development Goals, Report 98*; International Water Management Institute: Battaramulla, Sri Lanka.

Walsh, K. Shai, and L. & Mbangata, T. (2019). Assessing the Affordability of Water Services for Residential Consumers in South African Municipalities. WRC Report No. 2584/1/18.

Wang, H., Xie, J. & Li, H. (2010). Water pricing with household surveys: A study of acceptability and willingness to pay in Chongqing, China. *China Economic Review*, 21, 136-149. https://doi:10.1016/j.chieco.2009.12.001

Wanjara, A. O., & Ogembo, P. O. (2023). Impact of Climate Change on Health and Livelihoods of Pastoral Communities in Kenya: A Case of North Eastern Region. *Indonesian Journal of Social and Environmental Issues (IJSEI), 4*(3), 299-315. https://doi.org/10.47540/ijsei.v4i3.1078

Weststrate, J., Dijkstra, G., Eshuis, J., & Gianoli, A. (2019). The Sustainable Development Goal on Water and Sanitation: Learning from the Millennium Development Goals. *Social Indicators Research*, *143*(2), 795–810. https://doi.org/10.1007/s11205-018-1965-5

WHO (1997). *Guidelines for Drinking-Water Quality: Surveillance and Control of Community Supplies*; WHO: Geneva, Switzerland.

WHO and UNICEF (2021). Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF).

Zozmann, H., Klassert, C., Klauer, B., and Gawel, E. (2022). Heterogeneity, Household Co-Production, and Risks of Water Services — Water Demand of Private Households with Multiple Water Sources. *Water Economics and Policy*, 8, (1), 1-38.