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Community perception of land degradation across Maasai landscape, Arusha Tanzania: implication for developing a sustainable restoration strategy

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ABSTRACT

In Tanzania, most smallholder farming systems have experienced land degradation due to soil erosion which contributes to the decline in crop and livestock productivity. Community perception of land degradation has not been reported adequately in the Maasai landscape sufficiently reported, even though its causes and effects are site-specific and occur over time. This study assessed the community's perception of indicators, causes and land degradation management practices in the Maasai landscape. A total of 240 farmers from six villages distributed within three landscape zones differentiated by their altitudes and contrasting adoption of soil conservation practices were involved in the study. Farmer's plots, observations, discussions, and questionnaire interviews were used for data collection. Data analysis performed using Statistical Package for Social Sciences (SPSS) version 20.0 were descriptive statistics, and comparison tests were done using the Chi-square test. According to the results, 75% of the respondents recognize land degradation as a problem in their cultivated land. About 60% of the farmers reported anthropogenic as the most prominent type of land degradation in all landscape zones. Soil erosion was reported as the main indicator of land degradation accounting for 74.1%, 61.3%, and 44.4% in high, medium, and low landscape zones respectively. The study found that communities perceive the trend of land degradation as increasing in the landscape, whereby soil erosion and nutrient depletion are the major indicators of land degradation. The study recommends that the government and other soil conservation organizations in the Maasai landscape of Arusha and related areas consider community perceptions in the planning and implementation of interventions meant for sustainable land use and restorations. Communities in the Maasai landscape are aware of land degradation and have their indigenous method for conservation.

Keywords: Land degradation, Farmer's Perceptions, soil conservation practice, and soil fertility.

INTRODUCTION

Land degradation resulting from soil erosion and nutrient depletion are the major challenges that affect the environment, food security, and quality of life (Wickama *et al.,* 2014). This phenomenon affects billions of people in the world and it leads to over-exploitation of natural resources, decline in ecosystem provision, loss of vegetation cover and decline in rural livelihood (Masoudi *et al.,* 2021). Land degradation hinders the achievements of the United Nations Sustainable Development Goals and the land degradation neutrality challenge (Ifejika Speranza *et al.,* 2019). Land degradation impacts are higher in Sub-Saharan regions where about 65% of the land is considered degraded (Zingore *et al.,* 2015). The occurrence of severely degraded soils is very high. It accounts for about 350 million hectares (Ha) or 20 to 25% of the total land area, of which about 100 million ha is estimated to be severely degraded mainly due to agricultural activities. Land degradation costs Sub-Saharan Africa (SSA) about $68 billion annually and reduces the region's annual agricultural Gross Domestic Product (GDP) by 3% (Zingore *et al.,* 2015). Recent studies reported that about 75% of the land is degraded; predictions indicate that by 2050 this effect may surpass 90% (Perović *et al.,* 2021). This will mostly occur in the regions most vulnerable to land degradation including countries in SSA and particularly East and Southern Africa. The primary evidence of land degradation can easily be observed when the top layer of the soil is washed away by running water and poor vegetation or crop growth due to a lack of nutrients resulting from repeated removal with little to no replenishment. The problem is severe in sloping and marginal lands as a result of soil erosion(Ligonja & Shrestha, 2015). Reportedly, soil erosion affects about 61% of the total land of Tanzania (Nkonya *et al.,* 2015). In May 2019, the United Nations Food and Agriculture Organization (FAO) reported that crop production decreased by 0.4% per year due to erosion. This has considerably exacerbated the country's food crisis, affecting about 5 to 7 million people countrywide which compelling more than 45% of the population to live in extreme poverty and rely on aid every year (Negese *et al.,* 2021).

Land degradation has been a challenge since pre-independence in Tanzania. The Maasai landscape in Arusha is among the areas highly affected by land degradation due to unsustainable agricultural practices. To overcome this scourge, different soil conservation and restoration programs were introduced in different parts of the country including Arusha and Kondoa Irangi (Kajembe *et al.,* 2005). Later after independence, more projects were introduced in other parts of the country such as Soil Conservation and Agroforestry Project Arusha (SCAPA) in Arusha and Lushoto Tanga, Hifadhi Ardhi (Conserve land) in Dodoma and Shinyanga, Hifadhi Mazingira in Iringa and Kigoma Ujiji Soil Erosion Control Programme. These programs were unsuccessful due to low adoption resulting in increased land degradation across different parts of the country including the Massai landscape in Arusha (Kajembe *et al.,* 2005).

Many studies reported that many technical and institutional innovations developed and introduced in different parts did not appear successful in reducing the land degradation problem (Saïdou *et al.,* 2004; G. B. Tesfahunegn *et al.,* 2021). Several researchers have reported that mismatches between the proposed techniques and the current farming systems, lack of resources, poor market channels, and lack of local participation in the design, implementation, monitoring, and evaluation of the intervention technologies are some of the reasons why the introduced interventions against land degradation have not been successful (Atta *et al.,* 2016; Leach & Fairhead, 2000). According to Wickama *et al.* (2014), one of the factors contributing to the low adoption of sustainable land management strategies is the perception of land degradation by the community. Similarly, Negese *et al.* (2021) reportedly pointed out that the negative perception of farmers on contour terracing which they associate with rodent hiding sites, reduces the area of cultivation and compromises mechanization such as the use of oxen. However, research on community perception of land degradation to develop a management option for sustainable land use and restoration of degraded land has been given little attention.

Research studies have shown that local people in the community particularly farmers, possess significant knowledge of the indicators, causes, determinant factors, and conservation strategies. Farmers have been cultivating their land for many years during which they have gained experience and put their knowledge into practice to conserve their land. Understanding farmers' knowledge and perception of land degradation is important for the development of sustainable land restoration interventions (Kusimi & Yiran, 2011; B. G. Tesfahunegn *et al.,* 2011). Thus, understanding the farmer's perception of land degradation is an important factor if integrated for researchers and policymakers to design appropriate soil conservation measures and policies for recommendations respectively. The overall objective of this study was to assess the community's perception of land degradation in the Maasai landscape of Arusha, Tanzania. Specifically, the study had the following three objectives; (i) To assess community perception of land degradation particularly the indicators and their causes (ii) To assess community perception in identifying productive land and productivity of their farm (iii) To investigate community perception on existing and proposed soil conservation practices.

MATERIAL AND METHODS

Study Area:

The study was implemented in two districts in northern Tanzania; Arusha District Council, and Monduli District Council. The site was selected because it is among the highly affected areas by land degradation (Kalonga *et al.,* 2024; Rabinovich *et al.,* 2022). Arusha District Council is located South of the equator in between Latitudes ’3^0 10’$4^0$00’ and Longitudes 34^0 47’E-35^0 56’ East. 3º10'4º00'Sand Longitudes 34º47'E-35º56'E The climate of Arusha District is characterized by two rainy seasons, long and short rains. A long rain begins in April to early June while short rains begin in October to December and range between 800 mm to 1000 mm per annum. The mean annual rainfall is 900 mm with a temperature ranging from 16 ˚C to 33 ˚C throughout the year, cool weather is experienced from June to August with temperatures ranging between 16 ˚C and 28 ˚C. The average altitude is 1400 m above sea level. It consists of gently sloping hills separated by low granitic valleys. The vegetation type was originally savannah vegetation and some gallery forests (ADC, 2011).

Monduli district is located between 3.00” and 4.50' south of the Equator and 36.50' and 36.45' east of the Greenwich Meridian. The elevation varies between 600 m at the lowest height to 2900 m at the highest elevation above sea level. These are some of Tanzania's most arid areas, featuring a warm climate at low elevations and a cool climate at higher elevations. Temperature varies between 20 and 35 °C with annual rainfall distribution ranging between less than 500 to 900 mm in the lowlands and higher elevations respectively (Msoffe *et al.,* 2011). According to the Monduli District Council, tectonic activity and volcanism have a profound influence on the physical characteristics of the area, including terrain, geology, and soils (Kiunsi & Meadows, 2006). The region is dominated by shallow silt or silty clay soils. Isolated mountains (Monduli, Lepurko, Loosimingori, and Lengai) and flat rolling plains characterize the land surface. Forest, bushland, wooded grassland, and grasslands dominate the vegetation in the area. The area is mainly inhabited by the Maasai people, who are traditionally pastoralists. It is an important area for wildlife conservation since much of it is divided into game-controlled areas and it is also bordered by National Parks such as Manyara and Tarangire National Parks and the Ngorongoro Conservation Area (Kimaro *et al.,* 2017). These areas experienced significant environmental and socio-economic changes including population increase and changes in land cover and land use. The increase in agricultural activities through both small and large-scale farming has been cited as the most significant land-use change in recent years (Kiunsi & Meadows, 2006).

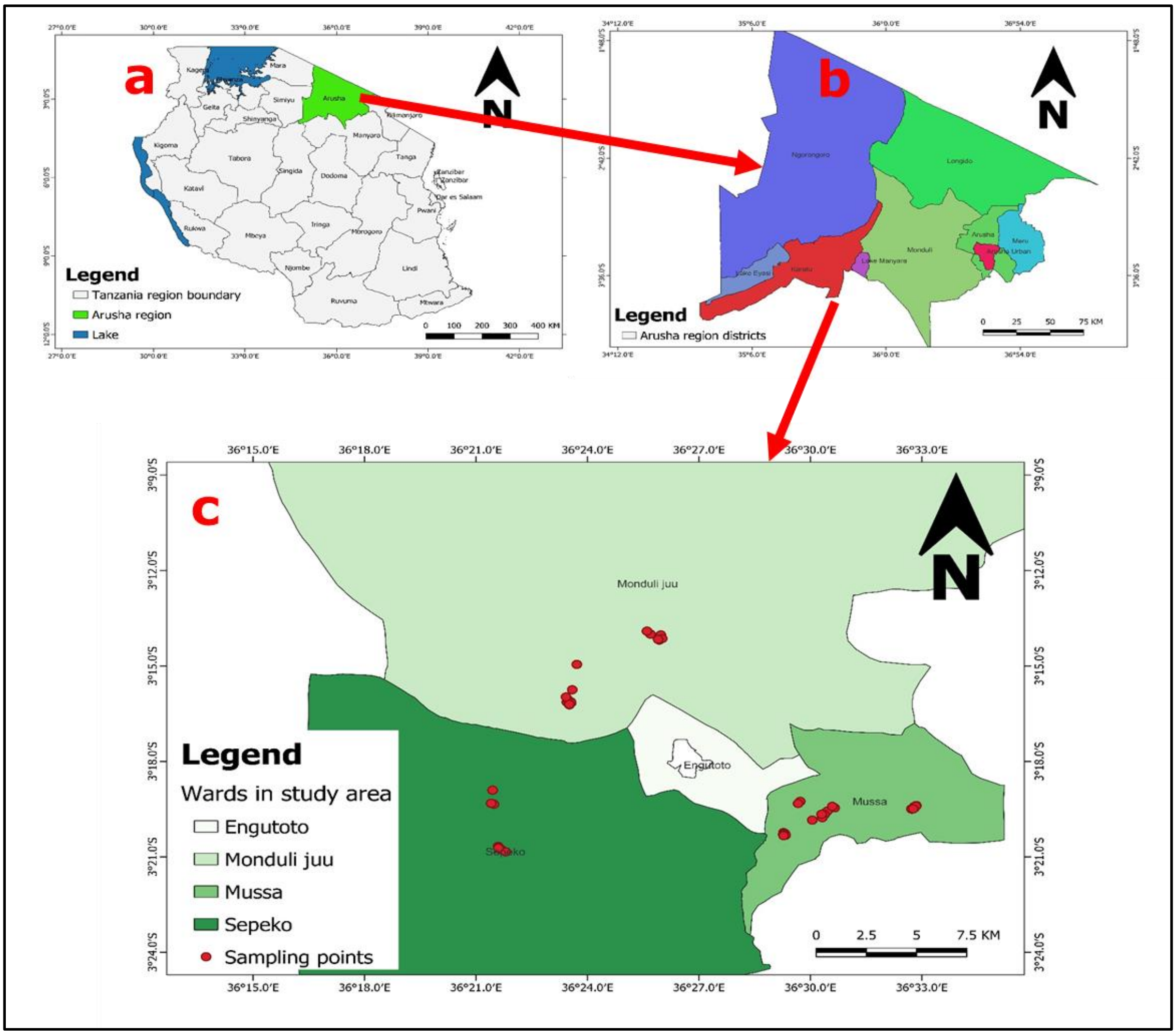

Fig. 1. Map of a study site showing sampling areas and their distribution. (a) Map of Tanzania, (b) map of Monduli and Arusha district, and (c) wards in a study area.

Design of the Study, Sampling Procedure, and Sample Size:

To determine the community's perception of land degradation and restoration strategies in the study area, a cross-sectional survey design was used. The selection of respondents for the study involved a multi-stage sampling procedure. At the initial stage, each district and one ward were selected and variations of altitude were recorded using a GPS device and stratified into landscape zones based on altitude, upper landscape zone (ULZ) (>1700 masl), middle landscape zone (MLZ) (1500 - 1700 masl) and lower landscape zone (LLZ) (<1500 masl). Villages selected for a household interview were Enguiki - ULZ, Emairate - MLZ, and Lendikinya - LLZ for the Monduli district and Likamba - ULZ, Oloitushula - MLZ, and Nengungu - LLZ for Arusha district. These villages represent different land degradation severity, sustainable land use practice intensity, and different land use practices which were observed during a reconnaissance survey. A list of farmers with more than 18 years old own one or more field plots and have been living in a particular area for not less than 10 years was provided by the village executive officer for each village. The study utilized a sampling frame consisting of 2045 households, which were identified from three wards encompassing six villages representing different landscape zones (Table 1). To ensure a representative sample, a random sampling technique was employed, resulting in the selection of 240 households, which accounted for 10% of the total households. This selection process was conducted using a probability proportionate to size sampling technique using the formula in equation 1 (Cochran, 1997). As shown in the formula, the results are shown in Table 1. This methodology is a modification of the methodology adopted from (Abazinab *et al.,* 2022).

$$S_V = \left(\frac{n_V}{N}\right) \times 240 \qquad \text{eq 1}$$

$S_V -$ Sample size selected in each village
$n_V -$ Number of households in a particular village
$N -$ Number of households in the study area

Table 1. Summary of farmer's households selected from all landscape zones

Wards	Villages	Landscape zones	Total households	Sample size
Mussa	Likamba	Upper Landscape Zone	405	49
	Oloitushula		397	48
	Nengungu		192	23
Monduli juu	Enguiki	Middle Landscape Zone	345	39
	Emairate		472	54
Sepeko	Lendikinya	Lower Landscape Zone	234	27
Total			2045	240

Data collection method:

To increase the response rate, a single visit multiple subject formal face-to-face interview style of household questionnaires and on-farm observations was used for data collection. Data collection was done from December 2021 to February 2023. Semi-structured questionnaires, focus group discussions to supplement the uncaptured information, and key informant interviews with agricultural extension workers, village executive officers, and elders. The tool focuses on obtaining information on the community's knowledge of local soil classification, drivers, and causes of land degradation as well as knowledge of the assessment of soil productivity. The semi-structured questionnaire covered the community's knowledge of local soil classification, drivers, and causes of land degradation as well as knowledge of assessing soil productivity. The questionnaire was written in the English language, however, the enumerators used common local languages (Swahili and Maasai) spoken by most of the community members in the region. Biophysical properties data of the field plots such as drainage, physiographic location, and surrounding topography were determined using the FAO Guideline for Soil Descriptions (FAO, 2006). Soil textural class was determined using the United States Department of Agriculture (USDA) soil texturing field feel-flow charts. An Open Data Kit (ODK) toolbox was used for the semi-structured questionnaire. Before the actual survey, a pilot survey was conducted with 18 households 9 in each district and 3 in each altitude zone. The aim of the pilot survey was; to check the relevance of the questions, familiarize the questionnaire with the local condition of the farmers, identify errors, clarify, and remove unnecessary statements and understanding of the questions to make sure enumerators understand the whole data collection process. Using pre-testing responses important modifications were conducted before starting the data collection exercise.

The designed questionnaire aimed to capture information on the biophysical properties of the surveyed field plots, types of land degradation, indicators of land degradation, main causes of land degradation, community's perception of the productivity of their field plots, productivity class, and current and proposed soil conservation practices. To validate the response obtained using questionnaires, six Focus Group Discussion was conducted one from each altitude zone.

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Soil sampling and analysis

Soil samples from each respondent field were collected for analysis of soil nutrient status to identify the most limiting plant nutrients. To collect soil samples, four points were taken from the centre of each field in the perimeter of three meters in a Y-shaped pattern. These four samples were then combined to make one composite sample. At each field, four soil samples were collected from a depth of 0-30 cm. Approximately 1000 grams of soil were collected using a handheld auger and stored in plastic zipper bags. These bags were then transported to the Soil and water laboratory at Nelson Mandela African Institution of Science and Technology Arusha-Tanzania for air drying and other preparation activities. After initial basic sample preparation, the soil samples were transported to the ICRAF Soil and Plant Spectral Diagnostics Laboratory in Nairobi, Kenya to predict soil properties using a Fourier-Transform Infrared spectrometer. Some samples were also analyzed using conventional wet chemistry. The predicted spectra were used to determine soil parameters using the AfSIS global models, which were tested using a reference set of samples. The models were developed using the Random Forest method.

Statistical analysis:

Data collected from the survey were processed, coded, organized and analyzed using IBM Statistical Package for Social Studies (SPSS) Version 20 Software. The descriptive statistics of percentages were used to summarize and present characteristics of the surveyed field plots, types of land degradation, indicators of land degradation, farmer's perception of the current status and trend of land degradation, community's perception of main causes of land degradation, current and proposed soil conservation strategies. A comparison of different landscape zones was performed using cross-tabulation and Pearson Chi-square (χ^2). The P value for their significance level was used to reference the two-sided test and its P value. A statistically significant P value <0.05 was considered statistically significant. The mean for the soil fertility status were used to classify and assign nutrient status based on proposed critical values for from other research findings.

To assess the trend of land degradation, a Likert scale was employed with three categories: 1 = increasing, 2 = decreasing, and 3 = remaining the same. Similarly, for the perception of productivity classes of field plots, a Likert scale was used with four categories: 1 = productive, 2 = moderately productive, 3 = degraded, and 4 = severely degraded. Drainage assessments utilized a scale with three categories: 1 = bad, 2 = medium, and 3 = good. Yes/No responses were represented using the labels 1 and 0 (Yes = 1, No = 0). Integer labels were utilized for responses related to land types, indicators of land degradation, causes of land degradation, farmers' perception of plot productivity, current conservation practices, and proposed soil conservation practices. To validate the response obtained using questionnaires, six Focus Group Discussions (FGD) were conducted one from each altitude zone.

RESULTS

Characteristics of the surveyed field plots:

During the survey, it was observed that loam soil dominated in all the plots surveyed in both locations with 83.3%, 84.2%, and 92.6% for the upper, lower, and middle landscape zones respectively. Except in the high altitude areas, there was a combination of a very small proportion of other soil types such as clay loam 2.4%, clay soil 4.8%, sandy loam 4.8%, sandy soil 2.4%, and silt loam 2.4%.

The nature of the physiographic location for most plots under the upper and middle Landscape zone was observed to have an average slope. The slope of the served farm plots was determined using a clinometer. As shown in Table 2, 69% of the surveyed plots in the upper landscape zone and 48% in the middle landscape zone were on an average slope, while 63.2% in the lower landscape zone were under low slope.

The surrounding topography of the surveyed area revealed domination of moderate flat nature 54.8%, 78.9%, and 66.7% for the upper, middle, and lower landscape zone respectively. Vegetation cover is mostly dominated by crops 45.2% followed by grasses 31% for the upper landscape zone, 52.6% of crops followed by 21.1% of trees at the middle altitude zone while 33% of trees followed by crops, and grasses 25.9% was recorded in the lower landscape zone. Results on drainage of their plots showed that 64.3% and 47.4% of the respondents from the upper landscape zone and lower landscape zone respectively reported that their farms had medium drainage while 59.3% of the respondents from lower landscape zone reported having good drainage.

Table 2. Surveyed field plot characteristics.

		Proportional of different plot characteristics in different Landscape Zones		
Category	**Characteristics**	**ULZ (%)**	**MLZ (%)**	**LLZ (%)**
Dominant soil textural classes	Clay loam	2.4	0.0	5.3
	Clay soil	4.8	7.4	10.5
	Loam soil	83.3	92.6	84.2
	Sandy loam	4.8	0.0	0.0
	Sandy soil	2.4	0.0	0.0
	Silt loam	2.4	0.0	0.0
Physiographic location	Average slope	69.0	48.1	21.1
	Low slope	19.0	37.0	63.2
	Top slope	11.9	14.8	15.8
Surrounding topography	Flat	0.0	11.1	15.8
	Moderately flat	54.8	66.7	78.9
	Wavy	7.1	11.1	0.0
	Other	38.1	11.1	5.3
Vegetation	Bare land	16.7	0.0	10.5
	Broadleaf plants	2.4	11.1	10.5
	Crops	45.2	25.9	52.6
	Grasses	31.0	25.9	5.3
	Shrub	0.0	3.7	0.0
	Trees	4.8	33.3	21.1
Drainage	Bad	11.9	3.7	36.8
	Good	23.8	59.3	15.8
	Medium	64.3	37.0	47.4

Soil nutrients status of the surveyed field:

The soil fertility parameters assessed in this study encompassed a comprehensive array, including pH, EC (Electrical Conductivity), CEC (Cation Exchange Capacity), SOC (Soil Organic Carbon), TN (Total Nitrogen), P (Phosphorus), K (Potassium), Ca (Calcium), Mg (Magnesium), Al (Aluminum), Fe (Iron), and Zn (Zinc). Table 3 presents the results detailing the soil nutrient status across the surveyed fields within the three distinct landscape zones. The findings of this investigation revealed a discernible trend in nutrient variations correlated with altitudes within the landscapes. For instance, certain soil fertility and nutrient elements like pH, CEC, Ca, and Mg exhibited an increasing trend with decreasing altitudes. Conversely, other essential nutrients such as EC, SOC, P, TN, Fe, and Zn displayed an upward trend with increasing altitudes. However, certain nutrient parameters did not exhibit a clear trend with altitudes, exemplified by observations indicating that CEC, Al, and K exhibited the highest values in the MLZ. These findings are consistent with similar studies reported by Kalonga *et al.* (2024) in their research characterizing nutrient status in the North North-East Maasai Landscape, Arusha Tanzania which reported that nutrient status varies depending on the altitudes in the Maasai landscape. The parallels between the two studies underscore the consistency and robustness of the observed patterns in soil nutrient dynamics across diverse geographical regions.

Table 3. Soil nutrient and chemical properties status of the surveyed fields in the Maasai landscape

Element	**ULZ**		**MLZ**		**LLZ**	
	Values	**Status**	**Values**	**Status**	**Values**	**Status**
pH	6.5	Moderately acidic	6.7	Moderately acidic	7.3	Slightly alkaline
EC (µS/cm)	114.28	Recommended	95.24	Recommended	111.93	Recommended
CEC (meq/100 g)	27.59	High	27.83	High	31.55	High
SOC (%)	1.89	Low	1.71	low	0.95	low
P (mg/kg)	14.87	Low	11.51	low	9.59	Low
TN (%)	13.5	Low	12.38	Low	9.61	Low
Al (mg/kg)	944.76	Optimum	953.07	Optimum	945.86	Optimum
Ca (mg/kg)	3117.75	Low	3196.28	Low	4006.06	Low
K (mg/kg)	184.99	Low	176.17	low	286.11	High
Mg (mg/kg)	522.96	High	599.74	High	599.86	High
Fe (mg/kg)	136.85	Optimum	129.5	Optimum	96.43	Optimum
Zn (mg/kg)	1.91	Optimum	1.7	Optimum	1.46	Optimum

Farmer's Perception of Current Status and Trend of Land Degradation:
Results on farmers' perception in regards to the current status of land degradation revealed that ≥75% of the respondents from all three zones; upper, middle, and lower landscape zones recognized land degradation as a problem in their cultivated land (Figure 2 (a). The chi-square test (χ^2 = 0.982, P = 0.913) indicated that the percentage of community members who perceived land degradation as a problem was not significant when compared to those who did not understand it. With regards to the trend of land degradation over the last 10 years, ≥70% of the respondents from each landscape zone reported an increase in land degradation in their cultivated land (Figure 2 b).

Types of Land Degradation:
Community members were asked about the types of land degradation based on causes (Anthropogenic or natural) occurring on their cultivated land. Anthropogenic was reported to be the most frequently mentioned type of land degradation by the community in all landscape zones by more than 60% as shown in Figure 2(c). Results from the chi-square test indicated that the percentage of respondents from different landscape zones who cited anthropogenic as a major type of land degradation was significantly (χ^2= 12.96, p = 0.002) higher than those who cited natural land degradation. Although all landscape zones reported anthropogenic as a main type of land degradation, the upper landscape was low (61.9%) compared to other landscape zones which reported more than 90%.

Indicators of Land Degradation:
Various indicators of land degradation were highlighted by the community members in their cultivated land and surrounding landscape. The majority of the people within the community were aware that land degradation indicators are in various forms that occur on their farmlands as well as in the surrounding environment. The commonly perceived indicators that were mentioned by the community members as being observed in the study area are shown in Figure 2 (d). Soil erosion was reported as the main indicator of land degradation in all three landscapes at 74.1%, 44.4%, and 61.3% in the upper, lower, and middle landscape zones respectively. Followed by nutrient depletion at 18.5%, 30.6%, and 29.0% in the upper, lower, and middle landscape zones respectively. The chi-square test showed no significant difference (χ^2 = 10.936, P = 0.090) in the proportion of respondents who mentioned soil erosion as a major indicator of land degradation.

Community's Perception of Main Causes of Land Degradation:
The major cause of land degradation identified by the respondents in their cultivated land and surrounding environment was overgrazing (Figure 2e). , with 32.6%, 25.6%, and 23.6% in upper, middle, and lower landscape zones respectively. This was followed by deforestation with 23.3%, 14.5%, and 14.0% in upper, lower, and middle landscape zones respectively. Other causes of land degradation reported were excessive ploughing, extractive farming, inappropriate farming, land use conversion, improper soil, and crop and animal management.

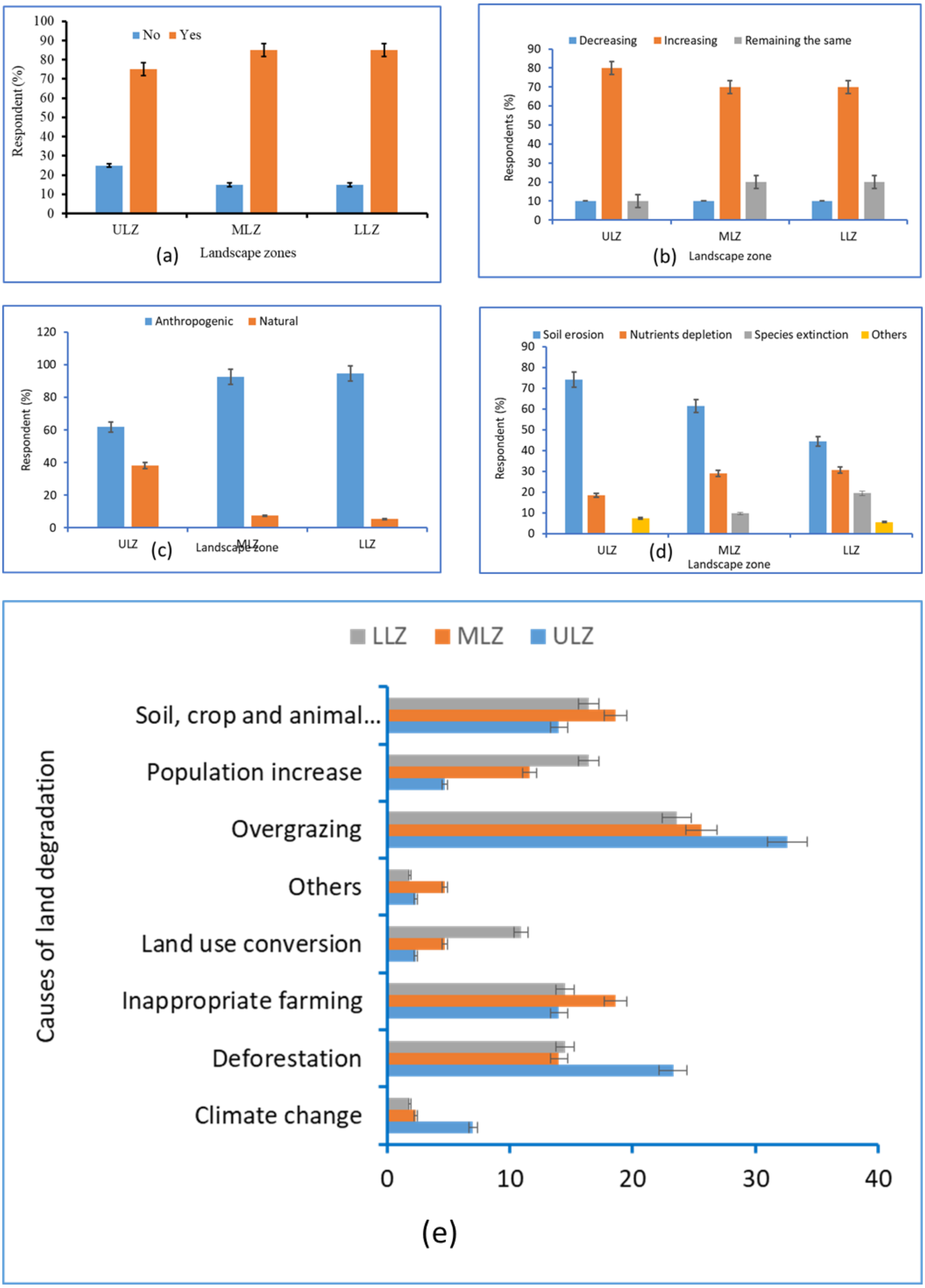

Fig. 2. Community's awareness of land degradation (a) awareness of land degradation, (b) trend of land degradation, (c) Types of land degradation, (d) indicators of land degradation, and (e) main causes of land degradation

Community's Perception of Productivity of Their Field Plots:

According to respondents, there were many long-term established ways used to assess productivity on their farms. The majority of the respondents from all landscape zones reported that broad-leaf plants are to be used for productive land (Figure 3a). Accordingly 50.0%, 75.0%, and 50.0% of the respondents from upper, lower, and middle landscape zones, respectively broad leaf plants were identified as a predominant technique used by farmers to identify productive land on their plots. Grasses were ranked second in the upper landscape zone 35% and lower landscape zone 20% except for the middle landscape zone where 30% of the respondents reported narrow leaf to be second after broadleaf.

When responding to the questions on how they identify productive land based on soil attributes, the majority of the respondents from all landscape zones responded that soil colour was the main soil attribute used to identify productive land with 45%, 55%, and 80 % from the upper, lower, and middle landscape zones respectively (Figure 3b).

Most of the respondents, 55%, 50%, and 45% from upper, lower, and middle landscape zones respectively reportedly use the yield of major crops per unit area to identify a productive land (Figure 3c). This was followed by crop response to fertilizers which was 30% in the upper landscape zone, 30% in the lower landscape zone, and 35% in the middle landscape zone to assess the productivity of their cropland. In regard to degradation, a high percentage of farmers from lower landscape zones 40% and middle landscape zone, and 35% reported that their farms are degraded (Figure 3d). In the upper landscape zone, a good number of the respondents (45%) reported that their land is moderately productive.

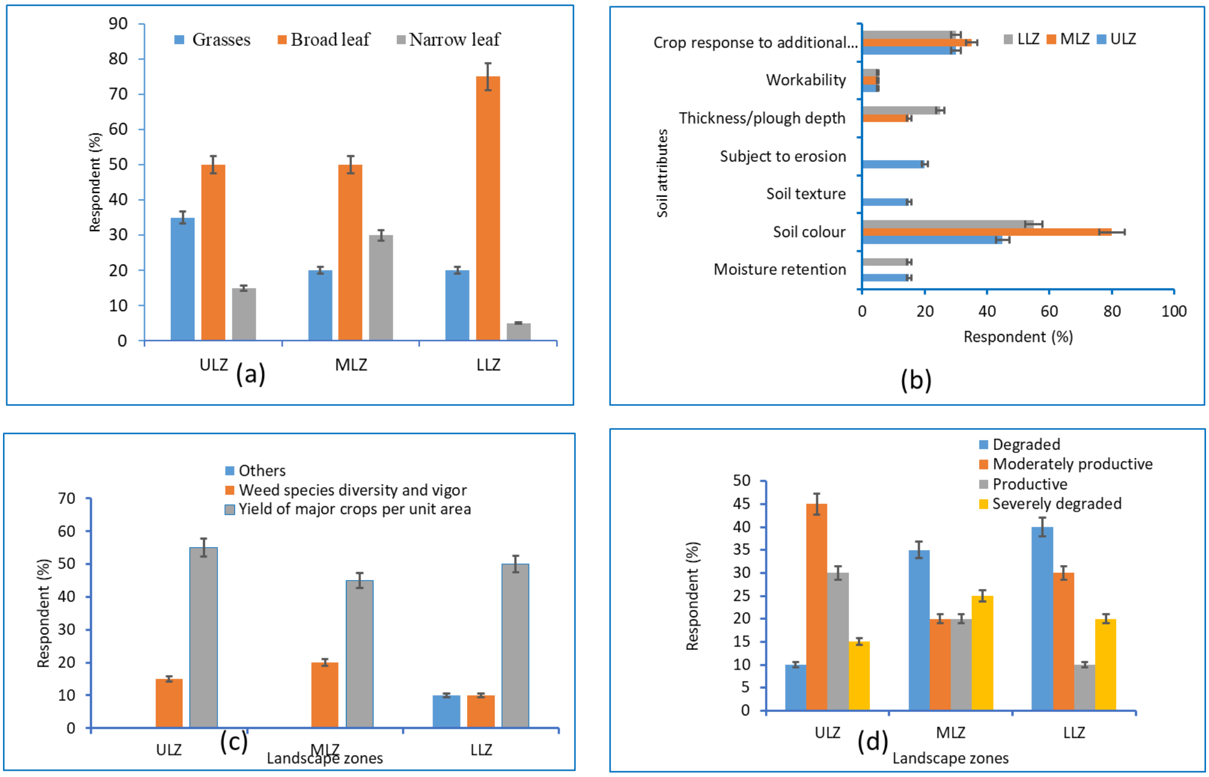

Fig. 3. Proportion of community's perception of productive land and productivity (a) Productive land based on dominant weed species, (b) based on soil attributes (c) based on crop weed performance, and (d) Productivity class

Current and Proposed Soil Conservation Practices:

During the survey different soil conservation practices currently practiced by farmers were recorded from their plots. In this study contour terraces ranked as the most effective soil conservation practice with, 30.3% of the farmers from the ULZ observed to use contours as a restoration strategy followed by cover crops 18.2%, agricultural intensification 15.2%, good agronomic practices, and other control measures were reported to be less than 10% (Figure 4a). In the LLZ, afforestation was observed to be the most preferred conservation practice currently practiced by farmers at 28.3%, followed by conservation tillage at 19.6%. In the MLZ, good agronomic practices and contours are recorded as the most preferred conservation measures currently practiced by farmers up to 25%, followed by cover crops at 13.9%. Although most of the farmers had at least some initiative to conserve their farms from land degradation, some farms were recorded with no conservation measures. During the survey, it was recorded that LLZ areas recorded a high percentage (13%) of the farms with no kind of conservation measures followed by the MLZ which recorded 11.1% while the ULZ had a low percentage (9.1%) of farms with no kind of conservation measures. The chi-square test (χ^2 = 20.018, P = 0.067) showed no significant difference among the existing soil conservation practices recorded in different plots in the Maasai landscape.

Based on the community's perception of land degradation conservation measures, farmers were asked to propose effective control measures based on the observation on their farms. Most of the farmers (40%) from ULZ and MLZ (25%) proposed contours as an effective control measure to be adopted. In the MLZ, 25% of the farmers proposed crop rotation, followed by 20% who proposed fallowing as an effective control measure (Figure 4b). The chi-square test showed no significant difference (χ^2 = 32.321, P = 0.183) among different soil conservation practices proposed by community members.

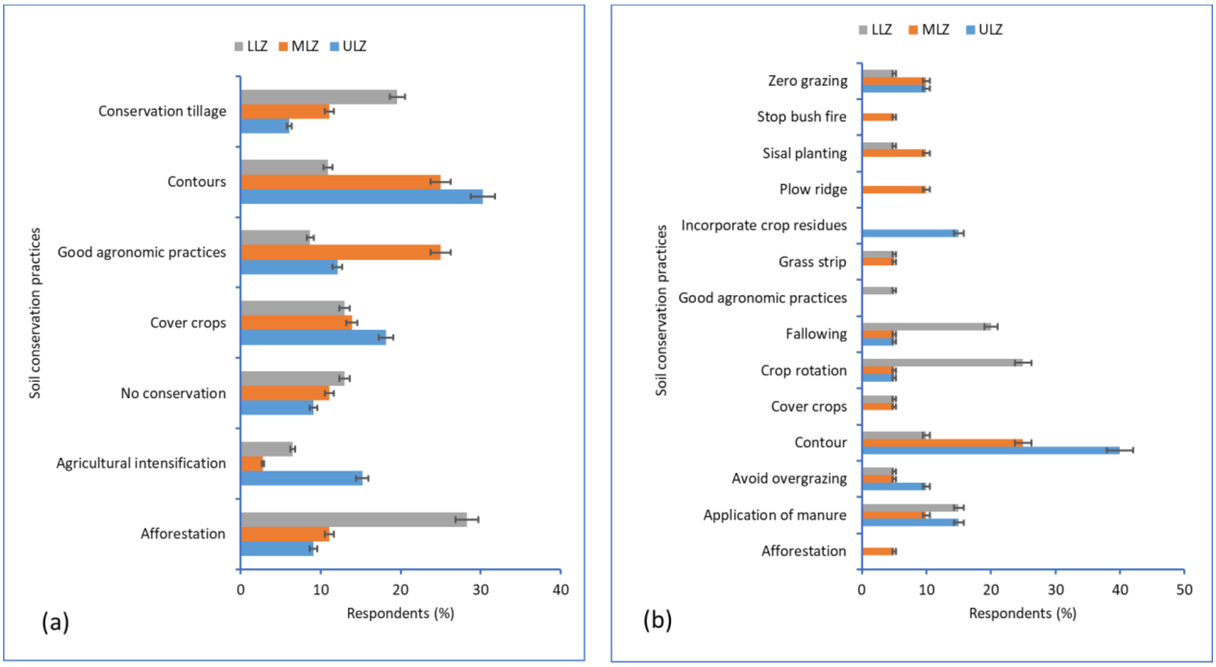

Fig. 4. Community perception on soil conservation practices: (a) Existing soil conservation practices (b) Proposed soil conservation practices

DISCUSSION

Biophysical characteristics of the soil influence the rate of land degradation through the effect of physical properties of the soil, surface cover and slope steepness (Lestariningsih *et al.,* 2018). Data collected revealed that the Maasai landscape spans from an average and low slope, with a moderately flat surrounding environment. According to FAO, (2006) and Tolosa *et al.* (2019), slope category is related to sensitivity to soil erosion, whereby average and moderate slopes are less sensitive to marginally sensitive to soil erosion respectively.

Loam soil was a dominant soil type with medium drainage for high and low-altitude areas, whereby crops and grasses are the dominant vegetation cover. The dominant soil type which is loam soil may be due to the geological parent material which may contain a significant proportion of minerals that weather into sandy loam particles. According to Kuok *et al.* (2023) loam soil has good drainage, a high infiltration rate, and a high ability to hold plants nutrients. The area was found to be dominated by crops as a surface cover which indicates human activities which destroy the natural vegetation cover in the study area. The observed characteristics of the farm plots surveyed do not favour land degradation rather than the human activities such as crop production, deforestation, and bushfires conducted in these areas which may accelerate land degradation as reported by other studies (Verhoeve *et al.,* 2021; Wynants *et al.,* 2021).

The study indicated that anthropogenic factors are the major type of land degradation in the Maasai landscape. These findings are in line with the previous studies in Ethiopia (Adimassu *et al.,* 2013; Assefa & Hans-rudolf, 2016; Tesfahunegn, 2019) and Southern Benin (Félix *et al.,* 2015) which reported significant differences in the number of farmers who reported anthropogenic as the major type of land degradation in their farmland. This could be because traditionally Maasai livelihoods are centred on livestock keeping, and overgrazing can occur when there are too many animals for the available land. Continuous grazing without proper rotational systems or rest periods can lead to soil compaction, reduced vegetation cover, and the degradation of pastures (Halde *et al.,* 2011).

The results revealed that many traditions have been established within the community to monitor and evaluate the status of their land. Continuous increase of gullies and rills and decline in healthy and vigorous crop growth in the cultivated land and the surrounding environment was used as an indicator of land degradation. Under these circumstances, many farmers use soil erosion as the main indicator of land degradation in the Maasai landscape. The results corroborate with other studies conducted in South Africa (Olivier *et al.,* 2023). To supplement these results, other studies conducted in the highlands of Ethiopia cited land degradation as a result of water erosion as the most common indicator of land degradation (Blake *et al.,* 2018; G. B. Tesfahunegn, 2019; Teshome *et al.,* 2013). The over-cultivation of the land in continuous tillage without nutrients replenishment, followed by grazing on crop residues, and removal of vegetation cover, has left the soil bare facilitating runoff which leads to soil loss and depriving both nutrients including organic matter.

Apart from the above, the study reported that most of the members of the community are aware of the existence of land degradation in their environment. The results are consistent with other studies conducted in Tanzania (Wickama *et al.,* 2014) and Ethiopia (G. B. Tesfahunegn, 2019). In addition, field observations from visits to the farmers' field plots, showed that they were highly affected by gully and rill erosion. This observation explains why farmers are often aware of land degradation problems in their cultivated land. Community awareness of land degradation problems is due to their experience in the particular area. Their livelihood depends on land for cultivation and livestock keeping over centuries and the information that they got from different projects established for soil conservation and restoration in the 1980s. This land use experience contributed to their perception of land degradation as a problem and its trend.

In line with this study, previous studies have reported that anthropogenic factors such as overgrazing, unsustainable land use practices, and over-cultivation, have resulted in extreme land degradation in Sudan (Abdi *et al.,* 2013), in Sub-Sahara Africa (Aksakal *et al.,* 2011; Kiage, 2013) and African rangelands *(Karyotis et al.,* 2011). However, due to heterogeneity between locations it is believed that the causes and severity of land degradation are site-specific. The reasons for the increase in water erosion over the years could be due to increased deforestation, increased susceptibility of soil to land degradation, and inappropriate soil conservation practices. During the reconnaissance survey in the study sites gullies and rills were abundantly observed in the farms, an indication that the farmers are aware of soil erosion. Moreover, the reasons for overgrazing being the main cause of land degradation may be because most households involved in the questionnaire are Maasai, whose sign of wealth is tied to livestock keeping and who would like to maximize their herd size for their own social, cultural, and economic reasons. This perception tends to encourage overgrazing which results in land degradation in the form of soil erosion.

The study revealed that farmers in the Maasai landscape use soil colour to determine soil fertility in their farms. These observations correlated with the previous study conducted in Tanzania which reported that farmers perceived that darker soil (Mbuga soil) is more fertile than the other soils (Lamboll *et al.,* 2001). Furthermore, several studies, including those from America Barrios & Trejo, (2003), Ethiopia Corbeels *et al.* (2000), Ghana Dawoe *et al.* (2012), and Kenya (Yageta *et al.,* 2019) concluded that farmers utilize soil colour as a common indicator to categorize soils in many different regions of the world. According to the community, based on experience, darker soil continuously gives good crop yields, because of its great ability to retain water, is simple to work, has abundant wet worm casts, produces more crops and plants with big green leaves, and has a huge number of soil living organisms.

The MLZ is termed as degraded due to the high runoff from the upper landscape which carries the soil nutrients to the LLZ. The moderate productivity in the ULZ could be due to the presence of soil conservation practices and the presence of high plant species richness due to the high amount of precipitation which contributed to organic matter in the soil. This observation supports other studies done by Kalonga *et al.* (2024) in the northeast of the Maasai landscape in Tanzania.

The variations in soil fertility and nutrient status across the surveyed landscape zones can be attributed to several factors, particularly altitude. The elevation-dependent increase in electrical conductivity (EC), soil organic carbon (SOC), phosphorus (P), total nitrogen (TN), iron (Fe), and zinc (Zn) could be influenced by altitude-related factors such as cooler temperatures, higher precipitation, and decreased weathering rates at higher elevations. Conversely, the increase in soil pH, cation exchange capacity (CEC), calcium (Ca), and magnesium (Mg) with decreasing altitudes may be attributed to enhanced mineral breakdown and release of calcium and magnesium ions from parent materials due to higher temperatures and increased weathering rates. Additionally, reduced rainfall and increased evapotranspiration at lower altitudes may contribute to concentration effects, further elevating soil pH and nutrient availability. However, the lack of clear trends observed in certain nutrient parameters like CEC, aluminium (Al), and potassium (K) across altitude gradients may be attributed to complex interactions between various soil-forming factors such as parent material composition, soil texture, land use history, and anthropogenic inputs. Moreover, localized variations in soil properties and landscape characteristics within each zone could contribute to the heterogeneity of nutrient distributions. Furthermore, geological and pedological processes, including erosion, sedimentation, and soil leaching, may also influence nutrient dynamics across the landscape.

Regardless of the increased problem of land degradation in the Maasai landscape, communities are using some soil conservation practices which vary from one landscape to another. Contours are the current major soil conservation measure for the upper and middle landscape while afforestation is for the lower landscape. Similarly, Kajembe *et al.* (2005); Lasway *et al.* (2020); and Ligonja & Shrestha, (2015) reported contour terraces as a dominant soil conservation technique currently used by smallholder farmers in Tanzania. This might be because when the problem of land degradation was reported in the Maasai landscape, the focus was on the mountainous areas (ULZ). The best conservation practice in mountainous areas was contour terraces, hence through SCAPA in 1989 – 2000 contours terraces were preferred over other conservation techniques. The adoption of contours terraces passed from generation to generation as a result it has dominated many parts of the Maasai landscape.

Moreover, the majority of the community members proposed contours for the upper and middle landscape zone while crop rotation was proposed for the lower landscape zone. These findings are attributed to most of the community members having prior experience and knowledge on the establishment of contours obtained from different organizations implementing different soil conservation projects in their area. Although in some area's contours are established and land degradation is increasing, interestingly they still propose contours as a soil conservation measure which suggests limited information on other soil conservation control techniques. Moreover, most of the farmers from lower landscapes proposed crop rotation followed by fallowing; this may be because most of their plots are flat which is not suitable for the contours.

CONCLUSION

This study aimed to evaluate the community's perception of land degradation in the Maasai landscape of Arusha, Tanzania. According to the findings of this study, communities perceived that the rate of land degradation is increasing, whereby major indicators of land degradation are soil erosion and nutrient depletion. Farmers in the landscape use the presence of broad-leaf plants, soil colour, and yield of major crops to identify productive land. Based on farmers knowledge, the fertility status of their field plots ranges from moderate productive to degraded whereby soil analysis results identified TN, P, K, Ca and Mg as the most limiting plant nutrients in the landscape. The current dominant soil conservation practice is contour terraces for the Upper and Middle landscape zones. At the same time, afforestation is the dominant soil conservation practice for the LLZ. However, most proposed soil conservation for the ULZ and MLZ is contour terraces and crop rotation for the LLZ.

To have a wide variety of options for choosing the appropriate measures in accordance, it is necessary to increase farmers' understanding of various soil conservation techniques. More participatory research on sustainable land management practices is necessary to restore degraded land in the landscape. Such interventions should consider heterogeneity in the study area in the design and promotion of conservation practices. Additionally, these findings suggested policy implications for the public inclusion of sustainable land management techniques and training programs, as well as the integration of indigenous land management practices into research and training platforms to promote sustainable and enhanced living.

Declarations:

The data collection instrument (household questionnaire) was reviewed for ethical clearance and approval by the government of Tanzania through Monduli District Council (MDC) with reference number BD.540/738/18/41. Additionally, informed consent was obtained from all the interviewed households participating in this study.

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تصور المجتمع لتدهور الأراضي عبر المناظر الطبيعية في الماساي، أروشا تنزانيا: الآثار المترتبة على تطوير استراتيجية استعادة مستدامة

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في تنزانيا، شهدت معظم نظم زراعة أصحاب الحيازات الصغيرة تدهور الأراضي بسبب تآكل التربة مما ساهم في انخفاض الإنتاجية. على الرغم من الجهود المتكررة التي بذلتها الحكومة لإدخال ممارسات الحفاظ على التربة، إلا أن اعتمادها كان أقل نجاحًا مما أدى إلى الزيادة المستمرة في تآكل التربة. أجريت هذه الدراسة في منطقة ماساي الطبيعية في أروشا، تنزانيا لتقييم تصور المزارعين بشأن تدهور الأراضي. شارك في الدراسة ما مجموعه 240 مزارعًا، وست قرى موزعة على ثلاث مناطق مختلفة حسب ارتفاعاتها وتباين اعتماد ممارسات الحفاظ على التربة. تم استخدام قطع الأراضي والملاحظات والمناقشات والمقابلات مع المزارعين لجمع البيانات بينما تم تحليل البيانات باستخدام الإحصاء الوصفي، وتم إجراء اختبارات المقارنة باستخدام مربع كاي. ووفقاً للنتائج، فإن 75% من المشاركين يعتبرون تدهور الأراضي مشكلة في أراضيهم المزروعة. وأشار حوالي 60% من المزارعين إلى أن تدهور الأراضي الناتج عن النشاط البشري هو النوع الأبرز في جميع مناطق الارتفاع. تم الإبلاغ عن تآكل التربة باعتباره المؤشر الرئيسي لتدهور الأراضي الذي يمثل 74.1% و61.3% و44.4% على الارتفاعات العالية والمتوسطة والمنخفضة على التوالي. من هذه الدراسة، وجدنا أن المجتمعات ترى أن اتجاه تدهور الأراضي يتزايد في المناظر الطبيعية، حيث يعد تآكل التربة واستنزاف المغذيات من المؤشرات الرئيسية لتدهور الأراضي. تشير هذه النتائج إلى أن الحكومة وغيرها من منظمات الحفاظ على التربة في منطقة ماساي الطبيعية في أروشا والمناطق ذات الصلة تعتبر تصورات المجتمع بمثابة إمكانات في تخطيط وتنفيذ التدخلات المخصصة للاستخدام المستدام للأراضي وترميمها. تدرك المجتمعات المحلية في منطقة الماساي الطبيعية مدى تدهور الأراضي ولديها أسلوبها الأصلي في الحفاظ على البيئة. عند تصميم استراتيجيات الحفظ، ينبغي أخذ تصور المزارعين لتدهور الأراضي في الاعتبار.

الكلمات المفتاحية: تدهور الأراضي، وتصورات المزارعين، وممارسات الحفاظ على التربة، وخصوبة التربة.