Contemporary Agricultural Land Management Practices under Climate Change and Population Increase Scenarios. Insights from Tanzania's Southern Highlands

ABSTRACT

This study investigated the impact of population growth and climate change on land management practices. The study was conducted in Mbinga district located in the Southern Highlands of Tanzania. Quantitative and qualitative research approaches were employed. Research data were collected using structured questionnaires, in-depth interviews, physical observation, focus group discussions and literature review. A total of 267 household heads were selected for this study. Also, the study used climate data from Tanzania Meteorological Authority, temperature and rainfall data over the past 40 years were collected (1981-2021). The findings revealed that, the area has experienced increased population and climate change incidences. The trend line for both minimum and maximum temperatures indicate a substantial increased trends at (P= 0.0018, R^2=0.0005; P=0.0176, R^2=0.02359) respectively. Contrariwise, the area has experienced decrease in rainfall totals at (P= 0.4385, R^2=0.0008). It was revealed that, various traditional methods of land management practices including the use of animal manures, mulching, fallowing and the use of crop residues were affected by population increase and climate change. Farmers adopted new agricultural practices including the use of industrial fertilizers and reducing the size of contour terraces as the coping strategies for agricultural production against environmental deterioration caused by population increase and climate change. However, the sustainability of such practices is uncertain due to continued population increase and climate change scenarios. Therefore, the study recommends for introduction of sustainable land management practices that would instigate for sustainable food production for the changing population.

Keywords: Land management practices, Climate change, Population increase, Agriculture, Food Security.

1. INTRODUCTION

The world is facing multifaceted challenges associated with climate change and population increase. Climate change can contribute to land degradation by exposing unprotected soil to more thrilling conditions and straining the ability of the current land management practices to sustain resource quality [1,2,3]. With the growing world population, land requirements are also increasing so as to cover the food demand [4, 5, *6]*. Human expansion throughout the world has made agricultural sector to become a dominant form of land management globally. Agricultural ecosystems cover nearly 40% of the terrestrial surface of the Earth [7]. The rural people derive their livelihoods from agriculture. Thus, population and land-use trends are considered to be the main driving forces for agriculture. Human influence on the land is accelerating due to rapid population growth and increasing food requirements. Population growth is often described as a factor towardsland management changes. Increasing demand on food as a result of population growth has created more pressure on land resources.

Agriculture is an important sector in ensuring food security for the growing population [8, 9]. The growth of agricultural sector associated with population increase has been one of humanity's largest impacts on the environment. Human population is growing while land resources for production to meet their basic needs are limited. However, widespread land depletion influenced by human activities lead to falling of production [10]. Land resources depletion through agricultural practices is one of the most serious problems in both high and low land areas during rainy season. Similarly, with the current climate change scenarios, communities have been applying unsustainable farming practices so as to curb with food insecurity.

The current study adopted a pessimistic school of thought which foresees potential political, social and environmental deterioration as well as destruction of land for production. They make their case by referring to the current trends such as rapid world population growth, growing concentrations of carbon dioxide (CO_2) in the atmosphere, declining health of oceans, reduction in biodiversity and land degradation [11,12,13].Under pessimistic perspective, population is solely responsible for all environmental problems [14]. Population pressure reduces the availability of land for fallowing and driving the division of farm fields into small pieces (land fragmentation). The increase in demand for food necessitate the use of chemical fertilizer to ensure enough food production [15].

The practice of land management for agricultural production involves the use of different techniques including pits in conjunction with green manure, regular crop rotation, fallowing and mulching together with inter-planting, the use of chemical fertilizers as well as insecticides [16, 3]. Most studies on population and environment have addressed the problem of natural resourcedepletion by associating with population growth.However, very little have been investigated on the impact of population growth and climate change on land management practices. This created the need for the current study.

2. MATERIAL AND METHODS

The study was conducted in Mbinga district in Ruvuma region located in the Southern highlands of Tanzania. The selection of this district based on its involvement in agricultural activities. Besides, the orientation of the environment make people adopt various land management practices. The district is characterized by high population growth, in 2022 the total population of the district was 285,582 as shown in Table 1. Population has been increasing over the years and people have changed land use systems leading to reduction of land cover and increased deforestation [17]. Population in Mbinga district is unevenly distributed and most people settle in mountainous area especially in Matengo highlands,this has led to increased land intensification for agricultural production.

Table 1: Population of Ruvuma region in 2022

District	Population in (Number) for the year 2022		
	Male	**Female**	**Total**
Tunduru District Council	201,668	210,386	412,054
Songea District Council	89,947	88,258	178,201
***Mbinga District Council**	**141,271**	**144,311**	**285,582**
Mbinga Town	75,882	83,014	158,896
Songea Municipal Council	134,920	151,365	286,285
Namtumbo District Council	132,035	139,333	271,368
Madaba District	65,215	33,085	65,215
Nyasa District Council	93,494	97,699	191,193
Total	902,298	946,496	1,848,794

***Studied District.**

The study used both quantitative and qualitative research approaches which complemented each other in providing information on population growth and land management practices. Three wards out of the thirty-seven total wards which constituted 10% were selected using systematic sampling. The selected wards included Ukuta, Matiri and Kitanda as shown in Figure 1. In each ward, one village was selected for the study, namely; Barabara, Kitanda and Litoho villages. The three villages selected had a total of 805 households. Out of these total households, about 267 households were selected to represent the entire population in three villages. The sample size from the total number of households was obtained using Glenn's formula from [18].

$$n = \frac{N}{1 + N(e)^2}$$

Detemination of sample size for a study
Where by
n =sample size
N=Number of population (householdes)
e =is level of precision

Sample size $n = \frac{805}{1+805}(0.05)^2$

$$n = \frac{805}{1+805}(0.0025)$$

$$n = \frac{805}{1+ 2.0125}$$

$$n = \frac{805}{3.0125}$$

$$n = 267.21$$

The sample sizes taken for a study were 267 households

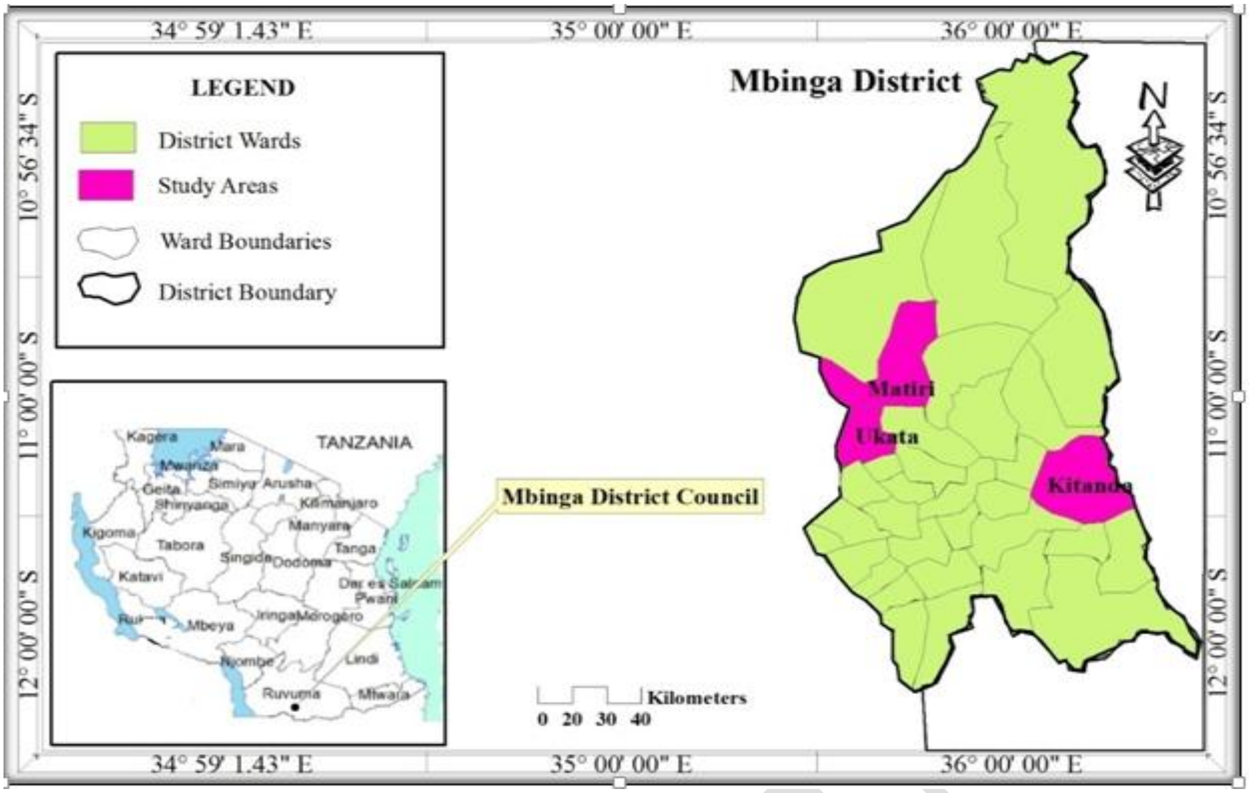

Figure 1: Location of the study area

Primary and secondary data sources were used so as to answer the research questions. Primary data were obtained through focus group discussions, interviews to key informants, observation and structured questionnaires to 267 selected household heads. Secondary data were obtained through literature review from different sources such as books, journals, district and ward profiles. Also, 40 years climatic data from Tanzania Meteorological Authority (TMA) covering a period between 1981 and 2021 were used in collaborating with socio-economic data provided by the household heads with regard to perceptions of climate change and their impact on land management practices. The obtained data were analyzed using various methods. Quantitative data from structured questionnaires were analyzed using IBM SPSS Statistics version 20. Descriptive statistics was applied to give frequencies for both multiple and single response questions. Qualitative data were analyzed basing on their content. Climatic data from Tanzania Meteorological Authority (TMA) were analyzed using Microsoft Office Excel. The data presented the patterns and trends of rainfall and temperature in the form of graphs.

3. RESULTS AND DISCUSSION

3.1 Respondents' characteristics

Land use choice is normally influenced by various demographic factors including the size of the household, age of the family members, gender, education level, employment status, attitudes, values, and personal traits of household members [19]. As indicated in Table 2, ages of the respondents in the study area ranged between 18 and 80+ years, whereby the majority (30%) were aged between 40 and 49 years and (25%) were aged between 30 and 39 years. This indicates that most of the respondents were in the working group as specified by the International Labour Organisation which suggest that the tiniest working age should be not less than 15 years [20]. In demographic studies age has been designated as one of the essential attribute deriving land use changes pioneered by agricultural practices. This is because various activities performed on the environment depend on the working age. Most of the respondents who participated in the study were farmers (72%). Thus, practicing agricultural production as their main economic activities for their livelihoods and hence dealing with land management practices for agricultural production. Many other studies taken in Tanzania have reported for agricultural activities as the main livelihood option despite the fact that the activity is susceptible to climate uncertainties [21, 22].

Table 2: Distribution of respondents by Age.

Age (Years)	Frequency	Distribution (%)
18-29	41	15
30-39	66	25
40-49	79	30
50-59	36	13
60-69	28	10
70-79	13	06
80+	04	01
Total	267	100

3.2 Climate situation in the study area

As in many other parts of the country, Mbinga district experience variations in various elements of weather. Majority of the respondents appealed to have witnessed changes of climate in their areas. Their perception based on their involvements in agricultural activities over longer time as well as their indigenous knowledge. The reported incidences included changes in rainfall patterns (onset and cessation), decrease in rainfall totals, changes in temperature as well as increased crop pests and diseases. The reported information formed a substantial baseline in comparing with meteorological data. These results are also in line with other scholars [23, 24].

The meteorological data revealed a sequential disproportion of temperatures whereby in 1981 the minimum average temperature was 15.2°C; this changed to 16.9°C in 2021. On the other side the maximum average temperatures changed from 29.7°C in 1981 to 28.2°C 2021. The trend line for both minimum and maximum temperatures indicate a substantial increased trends (P= 0.0018, R^2=0.0005; P=0.0176, R^2=0.02359) respectively as shown in Figure 2. Furthermore, Figure 3 demonstrates a frequent variation in rainfall totals over the past 40 years (1981-2021). The total annual rainfall had declined between 1068.5mm in 1981 to 901.5mm in 2021. The indicated trend line confirms for decreasing of rainfall at the rate of (P= 0.4385, R^2=0.0008). Similarly, the area experience changes in temperatures. These data corroborate with farmers perceptions who declared for changes in rainfall and temperature. Such situation has led to decrease in production and thus farmers adapt by engaging in framing practices which can degrade the land in a long run.

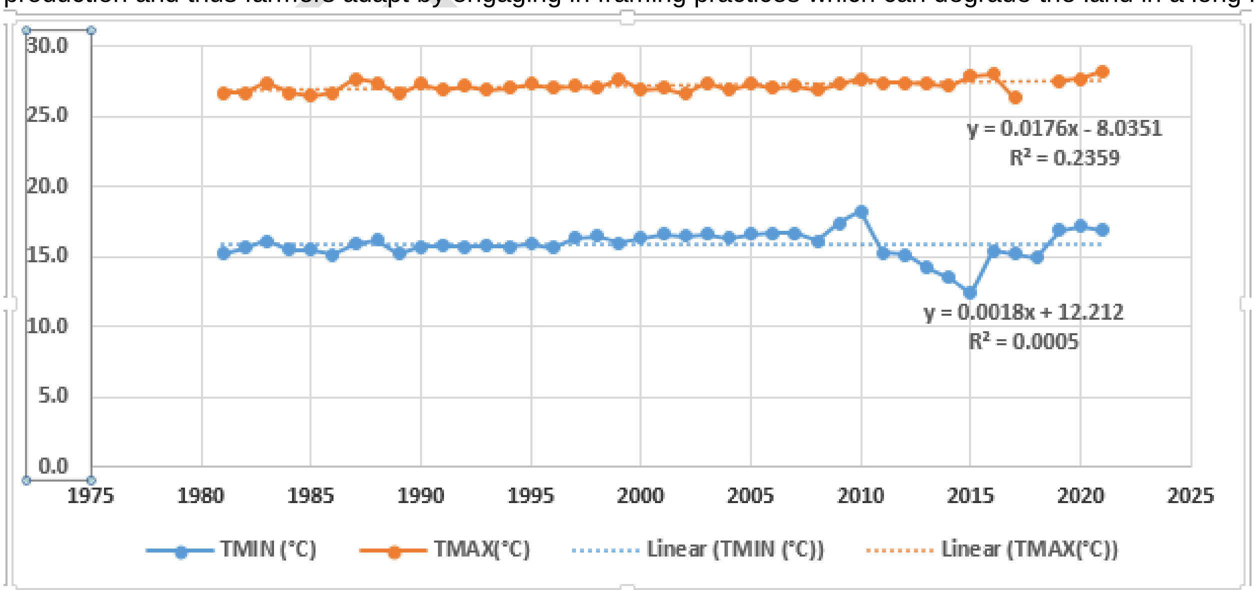

Figure 2: Minimum and maximum temperature in the study area from 1981-2021.

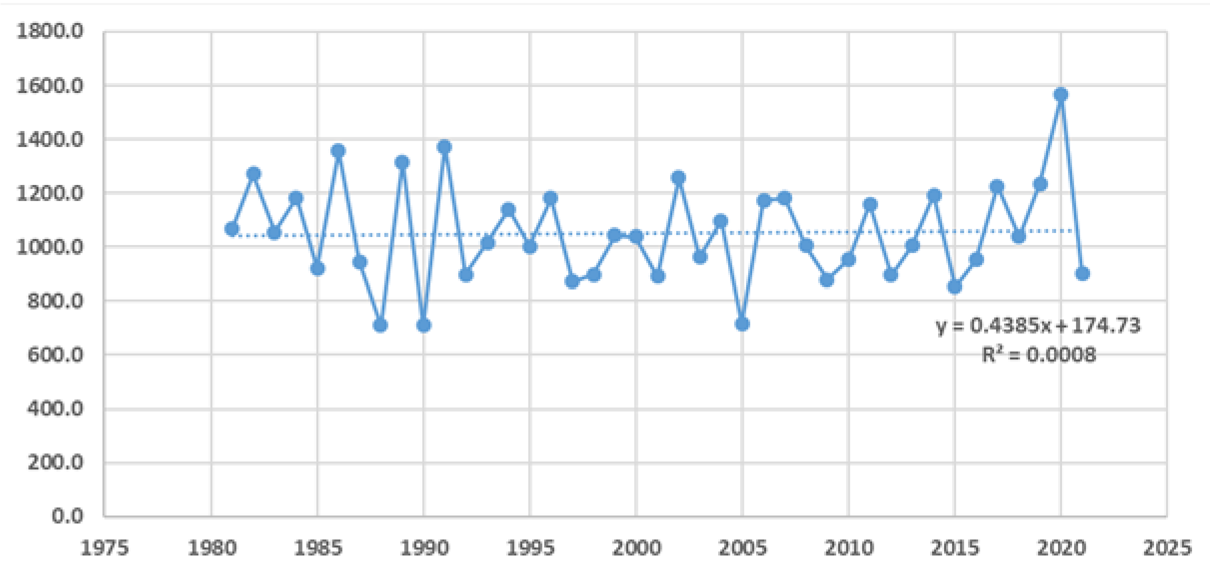

Figure 3: Total annual rainfall in the study area from 1981-2021.

Figure 4 indicates for variations in the onset and cessation of rainfall. In the study area, farmers reported to have observed such changes. Previously rainfall would start probably in the mid November and would end by April or May. But currently the situation has changed, farmers can no longer predict when the rain can start or end. The meteorological data over the past 40 covering the period between 1981 and 2021 confirmed for such variations. For instance in the years 1987, 1995, 2005 and 2010 the total monthly rainfall for November was very low recorded at 1.5mm, 1.1mm,0.0mm and 0.3 respectively, while in some years such as 1982, 2004 and 2014 the total monthly rainfall for November was 147.0mm, 125.0mm and 130mm respectively. On the other side, the total monthly rainfall for the month of December also kept varying over the years for instance in 1993, 1998 and 2006 the recorded rainfall was 34.5mm, 29.2mm and 309.1mm. These changes in the onset of rainfall has tremendous impact on crop production. Subsequently, rainfall cessation in the current years is early than previously. In Southern highlands of Tanzania which is characterized by unimodal rainfall pattern, rains ends between April and May, however with climate change, the area has experienced great variations example in 1981, 1994 and in 2017 the recorded total monthly rainfall for April was 105.1mm, 44.2mm and 204.9mm. Some months had no rainfall at all in the month of May example in 1997, 2004, 2016 and 2020 the area recorded 0.0mm. These oscillations in the onset and rainfall cessation affects crop yields and thus farmers find themselves engaging in practices that may have negative impacts on the environment. Similar observations were also reported by other scholars who observed for variations in the onset and cessation of rainfall in different parts of the world [25, 26].

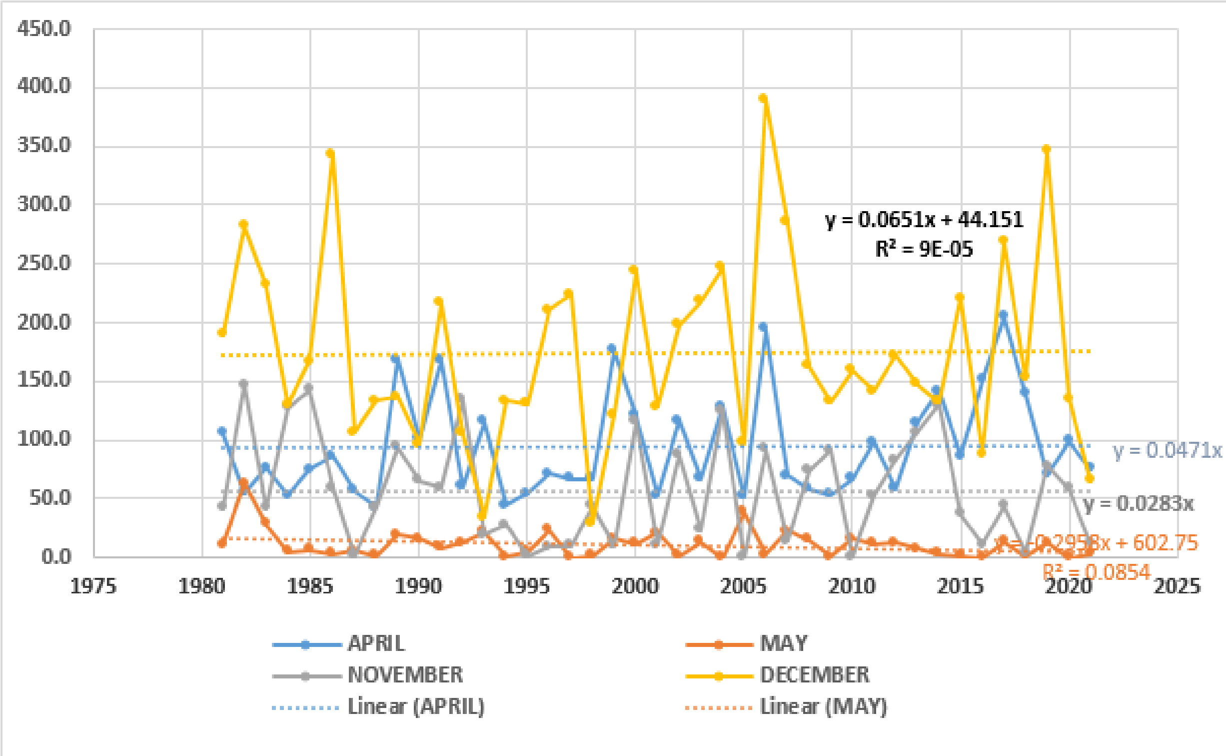

Figure 4: Monthly rainfall between November, December, April and May (1981-2021)

3.3 Land Management Practices in the study area

The respondents highlighted different methods used in land management for production. The methods based on the nature of crops grown and size of the farm. The crops grown in the study were maize (23%), beans (19%), coffee (22%), wheat (04%), vegetables in garden (16%), sweet potatoes (02%), bananas plantation (03%), cassava (06%) and groundnuts. These crops are divided into cash perennial crops and staple crops that are grown in small scale for food to feed the growing population. However, the dominant crops in the study area were maize. Over the years, maize has been reported to be the dominant cereal crop in Mbinga district. Observations done in Ruvuma region indicated that, Mbinga district had the largest area of maize (50,346 ha) followed by Namtumbo (28,809 ha), Songea Rural (28,503 ha), Tunduru (27,246 ha), and Songea Urban (4,600 ha) [27].It was reported that, in perennial crops, land management practices included; the use of mulching process, industrial fertilizer, animal manure, intercropping and crop residues. On the other hand, the use of Matengo pits (ngoro), fallowing, crop rotation and terracing were reported to be used in staple crops (Figure 5). However, population growth in the study area led to the magnification of various activities including expansion of agricultural land and establishment of infrastructures such as roads, residential houses and industries.

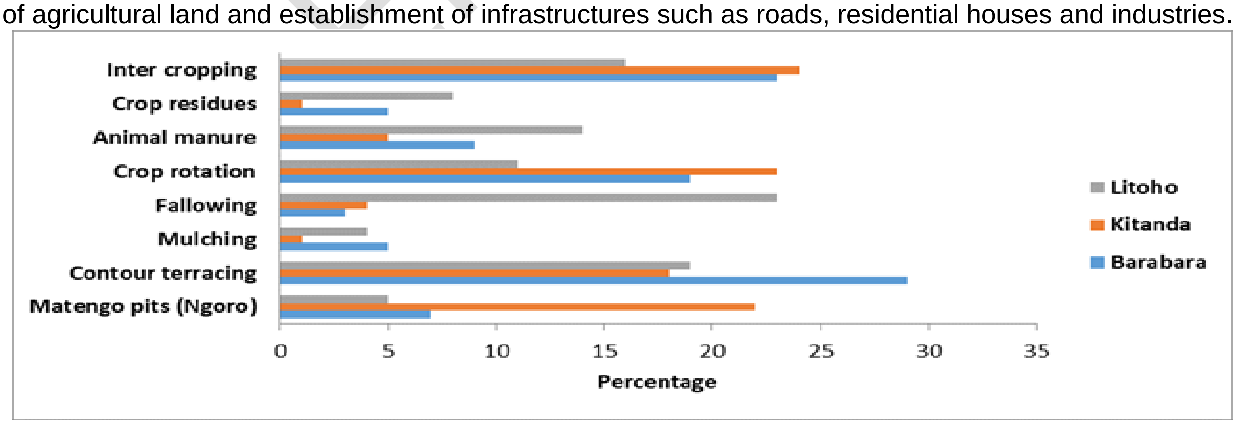

Figure 5: Land management practices applied in the study area

The use of ngoro techniques (Matengo pits) as a method of land management for production of staple crops was introduced since nineteenth century in Mbinga district [28]. The method was introduced due to nature of the district, which is characterized by both gentle and steep slopes in mountainous areas. The main farming activities are practiced during rainy season, which needs means for controlling soil erosion in highland areas. The Wamatengo have cultivated steep slope fields for more than two centuries using their indigenous knowledge of land management that is essential for storing water and controlling soil erosion [29, 30]. In the study area about (23%) of the respondents in Kitanda village reported to use *ngoro* technique for managing the land. The construction of *ngoro* requires many laborers and intensive participation because it comprises cleaning grasses and allowing them to dry for two to three weeks. Thereafter, they are collected and laid down in rows forming a gird all over the land intended for cultivation. This activity is mainly done by men. Then women cover the grasses with topsoil which is exhumed from the square area bounded by grass ridges. After the grasses have been covered completely, seeds of annual (staple) crops are sown such as beans and wheat. Also, the seeds sown are covered with sub-soil. At the end of season, crops are harvested and crop residues are placed in pits [31]. The circumstance implies that this method of land management is suitable in areas with high population growth and in mountainous areas so as to control soil erosion and degradation. The physical structures of *ngoro* technique of land management for production are shown in Figure 6.

Figure 6: Ngoro indigenous method of land management for crop production in steep slope area, used for storing water and control soil erosion during rainy season in the study area.

3.4 Population growth and changes in land management practices in the study area.

With increased population, the district has experienced changes in land management practices. Firstly there had been changes in ways of enhancing soil quality. Various studies report that; soil is where food begins, and it is estimated that about (95%) of food is directly and indirectly produced from soil. Population growth lead to increased demand for food grown from soil and thus contributing to overuse the soil due to the fact that, land resources are is limited/static while population is dynamic. Soil reduces its ability to support ecosystem goods and services through soil erosion, soil salinity, nutrient depletion, loss of biodiversity, soil pollution and loss of soil organic matter. In-order to return soil into productivity, it requires integrated nutrients management to maintain soil fertility. Also, soil fertility aims at supporting plant growth by providing sufficient oxygen, moisture and nutrients [32].

The study focused on two phases of population growth i.e before the year 2000 (period with low population) and between 2001 and 2022 (years with high population). When the area had low population ii.e before the year 2000, famers reported to have used several methods in enhancing soil quality including organic manure and crop residues, very few used industrial fertilizers and some people would even engage in crop production without enhancing soil fertility. It was revealed that, in some villages in the study area, example Barabara village, farmers (36%) reported to have used animal manure during crop production and (32%) admitted to engage in production without using neither manure nor industrial fertilizers. About (22%) reported to have used crops residues left at farm after harvesting to generate fertility. Also, a small number of respondents mentioned the use of industrial fertilizer at that time. At Kitanda village (31%) reported to have used animal manure and (34%) used mostly crops residues as shown in Figure 7.

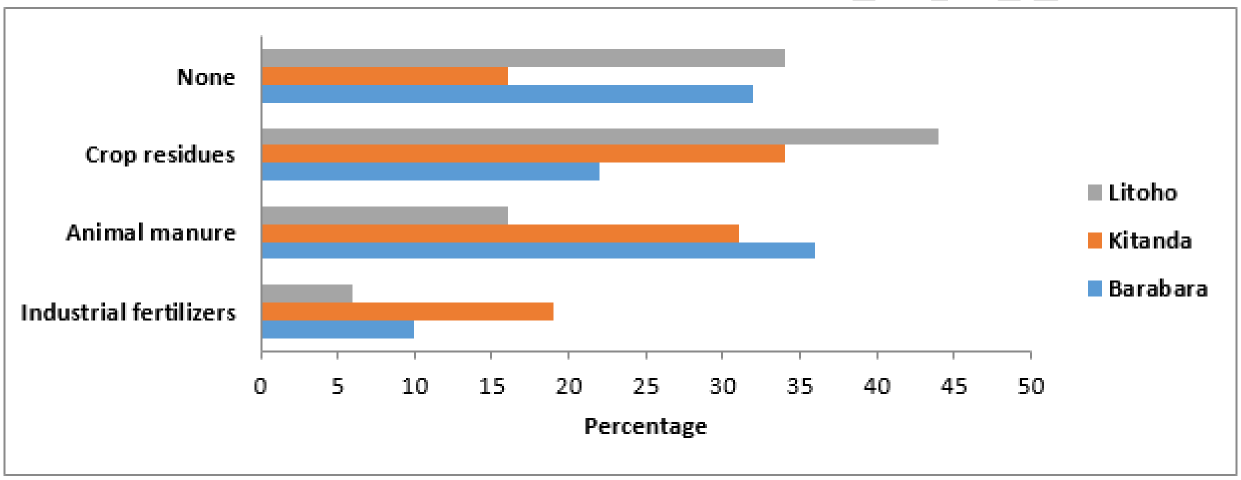

Figure 7: Ways of enhancing soil fertility before the year 2000

Starting from 2001-2022, methods for enhancing soil fertility changed with the increase of population and climate change so that farmers could produce more yields to feed the growing population. Industrial fertilizers were now mostly used in improving soil fertility compared to organic manure and crops residues which were dominant before the year 2000. The use of industrial fertilizers in Barabara village from 2001 became predominant as majority of the respondents (52%) admitted to use industrial fertilizers, the use of animal manure dropped to (24%) as indicated in Figure 8. In Kitanda village, industrial fertilizers were highly used for (64%) than it was before the year 2000. Other methods were used at small rate such as animal manure for (16%), crop residues (11%) and cultivating without using fertilizers dropped to (09%). Therefore, crop residues, use of animal manure and cultivating without using industrial fertilizers were predominant when there was low population growth before the year 2000. On the other hand, the use of industrial fertilizer became predominant during high population growth after 2001. Also, population growth has led into changes in fallowing periods. In the study area it was revealed that, the period of fallowing in plots while waiting to revert to their natural vegetation before 2000 and after 2000 had changed tremendously

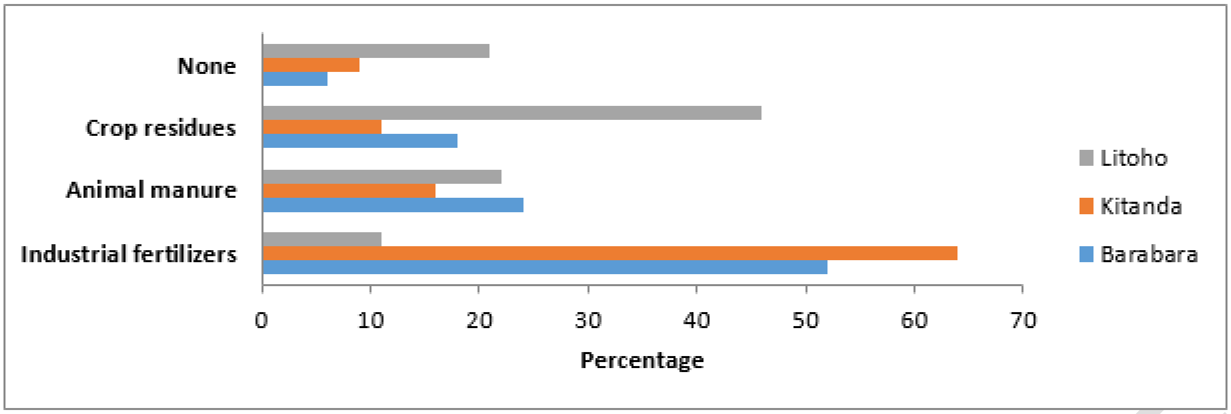

Figure 8: Variation in ways of enhancing soil fertility after 2000

Studiesby other scholars revealed that fallowing is highly practiced in rural areas where population is low and land for cultivation is available, thus, with increased population, fallowing changes and thus affecting the land [33]. The changes on methods of land management practices for agricultural production in Mbinga district has been associated with population increase and climate change which has led to increased demand for basic needs like food and settlement so as to accommodate the growing population. The situation paves the way towards changes to the period of fallowing and shortage of grasses for mulching.

4. CONCLUSION

The study examined the impact of climate change and population increase on land management practices. Population continue to increase while land resources for production are limited. In the light of the obtained findings, population growth contributes to the agricultural expansion that accelerates changes in land management practices. Similarly, climate change can lead to land degradation by exposing unprotected soil to more exhilarating conditions and draining the ability of the current land management practices to sustain resource quality. The findings revealed that, various traditional methods of land management including the use of animal manures, mulching, fallowing and the use crop residues are affected by population increase and climate change. This supports the idea by Malthus's (1798) that population increase lead to environmental deterioration. Besides, farmers had adopted new systems including the use of industrial fertilizers and reducing the size of contour terraces. However, the sustainability of the current land management practices is uncertain due to continued population increase and climate change. Therefore, the study recommends for introduction of sustainable land management practices that would instigate for sustainable food production while conserving the natural environment.

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