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Climate change adaptation strategies through traditional farming practices. The case of Matengo pits in Mbinga District, Tanzania

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A B S T R A C T

In most of the developing countries, agricultural activities have been practiced under traditional approaches. Majority of the farmers use indigenous knowledge in their farming activities for varying reasons. This study focused on Matengo pits as a traditional climate change adaptation strategy. The main objectives of this paper is to (1) identify the existing traditional agricultural practices, (2) ascertain the trend of climate change (1980-2021) and (3) evaluate the usefulness of Matengo pits in adapting to climate change. To achieve the research objectives, mixed research approach under descriptive design was used. A total of 133 heads of households were involved in this study. Primary data were collected through questionnaires, structured interviews, focus group discussions and direct observation. Secondary data were collected from published and unpublished documents. The study further used climate data from Tanzania Meteorological Agency on temperature and rainfall variations for the past 41 years (1980-2021). The Statistical Package for Social Sciences (SPSS) version 20 was used to analyze the quantitative data. Simple linear trend analysis was used to establish and test for rainfall and temperature trends. Findings from this study revealed that Matengo pits were among the traditional farming techniques employed in Mbinga district. It was realised that, the area experiences variation in temperatures and rainfall. Results for both minimum and maximum temperature indicate significant increasing trends (P= 0.0032, R^2=0.0016; P=0.0101, R^2=0.0575). Inversely, archival data from TMA show the decreasing trends of rainfall (P= 0.-04206, R^2=0.0007). The findings revealed that the use of Matengo pits contribute positively towards moisture retention, seed germination and amount of yields. The study recommends for adoption of Matengo pits technique in other areas for a sustainable crop production in this era of climate change and variability.

Keywords: *Traditional farming, Climate change, Adaptation strategies, Matengo pits*

1. Introduction

In many parts of the world where agriculture predominate, two farming approaches have been adopted namely; modern and traditional approaches. In most of the developing countries, agricultural activities have been practiced under traditional approaches. Majority of the farmers use indigenous knowledge in their farming activities (Jackson *et al.,* 2007). However, the outputs from agricultural sector in sub-Saharan Africa (SSA) have, in the recent years, remained lower than other parts of the world (FAO, 2009; ACET 2014). Numerous researchers attribute this to innate factors such as climate change, soil quality and crop diseases (Bjornlund *et al.,* 2018). Subsequently, food security has been an ongoing predicament, with 30% of SSA's population being food insecure (Pfister *et al.,* 2011).

Traditional knowledge has multiple applications in various fields such as agriculture, climate, soils, hydrology, plants, animals, forests and human health (Pulido and Bocco 2003). Over thousands years majority of the farmers have been using their local farming practices, this has resulted to the materialization of modern practices in different parts of the world (Koohafkan and Altieri 2010). Traditional agricultural practices are highly dominated by smallholder farmers. It has been reported that, globally about 84% of farms have area less than 2 hectares that operate in about 12% of farmland (Altieri 2004; Lowder *et al.,* 2016). In Sub Saharan Africa smallholder farmers comprise 80% of all farms and their traditionally cultivated fields are generally more productive than that of large-scale farmers (Kuivanen *et al.,* 2016).

There are various traditional agricultural practices including agro forestry, intercropping, crop rotation, cover cropping and traditional organic composting (Bjornlund *et al.*, 2018). These practices are not similar across the globe; they differ depending on the nature of the environment and the purposes for

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engaging in such farming practices. Native farmers in low developed countries have been performing their agricultural activities in vulnerable areas which are susceptible to extreme weather events. Farming under such harsh situation has made farmers to adopt farming systems which are resilient to environmental changeability with negligible external inputs (Altieri *et al.,* 2015). Indigenous farmers can observe changes in weather and climate in their areas and use several adaptive and mitigation strategies (Macchi *et al.,* 2008; Salick and Ross 2009).

Climate change and variability adds stress to our societies and to the environment; it is the predominant challenge of this century affecting various sectors including agriculture, water, health and infrastructure (IPCC, 2007; UNFCCC, 2007). Farmers in different areas have diverse insights and adaptation strategies to adjust with climate change. Farmers' perceptions to climate change contain a significant role towards adaptation strategies and policy designing as well as integration of scientific and native knowledge for climate change adaptation (Juana *et al.*, 2013; Woods *et al.*, 2017). In agriculture, climate change adaptation strategies started from when people started farming through making changes in agricultural practices (McLean 2010).

Climate change is generally detrimental for agricultural production. Therefore, there is an urgent need for sustainable adaptation and mitigation strategies. If adaptation methods are effectively undertaken, climate change impacts can be minimized. Environmental conditions, geographical location, socio-economic status, cultural differences and diverse knowledge systems influence perceptions of climate change and adaptation approaches (Touch *et al.*, 2016; Ayal and Filho 2017). Farmers with extensive knowledge about climate change and its impacts are better adjusted (Menapace *et al.,* 2015; Tesfahunegn *et al.,* 2016; Li *et al.,* 2017).

In Tanzania, as in many other developing countries, climate change has affected different sectors; agriculture inclusive. In order to acclimatize to varying climate farmers have been transforming their agricultural practices. The changes in farming customs are focused on both crop and livestock production. In Mbinga district, farmers have been adapting to changing climatic conditions through various traditional and scientific methods. However, the focus of the current study is on Matengo pits which are considered as an indigenous soil, water and nutrient conservation system for the sloping land. Matengo pits retain water and use crop residues to support the pits leading to improved and sustained soil fertility, crop productivity and reduced soil erosion (Nyasimi *et al.,* 2017).

Matengo pits as a technique of land management in sloped areas was introduced in the 19th century in Mbinga district. Farmers used this technique in producing staple crops (Malley *et al.,* 2004). The geographical orientation of the district which is characterised by both gentle and steep slopes influenced the introduction of Matengo pits. Farming activities in the area are normally undertaken during rainy season and soil erosion is likely to occur due to the steepness of the area. Thus, Matengo pits were introduced as an indigenous farming techniques characterized by a combination of anti-erosion techniques of pits and ridges on steep slopes.

The method is usefully in areas with high population and mountainous areas, the method supports the concept of 'more people less erosion' (Teffen, *et al*., 1994). Energetic laborers are required in preparing Matengo pits because the activity comprises various stages to its accomplishment. The activities include clearing grasses and allowing them to dry for two to three weeks, collecting the dried grasses and laying them down in rows to form a restrain all over the land proposed for farming. Then, digging the pits and covering the grasses with top soils. After the grasses have been roofed in the entire ridges, seeds of staple crops are sown (Edje *et al.,* 1988).

Although various studies have established the usefulness of Matengo pits, they have largely focused on soil conservation, water and land management thus yielding numerous faults when dealing with climate change scenarios (Moritsuk *et al.,* 2000; Malley *et al.* 2004; Nyasimi *et al.,* 2017; Nakamo 2021). Therefore, there is a need to ascertain an amalgamated study that interrogates traditional farming practices under climate change scenarios. The main objectives of this paper are to (1) identify the existing traditional agricultural practices, (2) ascertain the trend of climate change (1980-2021) and (3) evaluate the usefulness of Matengo pits in adapting to climate change.

2. Materials and Methods

2.1. The study area

The study was conducted in Mbinga district-Ruvuma region which is located at the edge of the Great Rift Valley and encloses numerous mountains, including the Livingstone ranges and Kitesaliwili Mountains. The distinctive feature of the Matengo highlands has been exhaustive farming of the steep mountains slopes. The selection of this area focused on the predominance of Matengo pits for several years.

2.2. Approaches and design

The study used the mixed approach in which a combination of qualitative and quantitative approaches formed the basis for data collection and analysis. The quantitative data were collected through questionnaires from the households engaging in farming activities. Qualitative data were collected through observation, interviews and focus group discussion. The study used a descriptive research design; this is an appropriate design when the research aim is to identify characteristics, frequencies, trends, and categories.

2.3. Sample and sampling procedures

For a sample to be representative enough for statistical analysis, it is recommended to select at least 10% of the population in the study area. The study area had 28 wards, therefore, a total of 3 wards were selected, namely; Mikalanga, Kambarage and Mpapa. From each of the selected wards, one village was selected including Ilela, Matekela and Mitawa respectively.

In obtaining a sampling frame which was significant in determining the sample size, village executive officers were consulted and provided a list of farmer households. The lists were compiled and it was found that the selected villages had a total of 3148 farmer households as shown in Table 1. The obtained sample frame was used in determining the sample size.

Table 1. Total number of farmer households in each village

Ward	Village	Number of Households
Mikalanga	Ilela	1368
Kambarage	Matekela	914
Mpapa	Mitawa	866
Total		**3148**

Source: Survey data 2022

2.4. Sample size

The determination of sample size for structured interviews was based on confidence and precision level. In social science research, 95% confidence level with the precision level of 5% or 0.05 is adequate. The population for this study was finite and therefore sample size was determined using formula given by Kothari (2004) as:

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2\ (N-1) + z^2 \cdot p \cdot q} \quad \text{……………………………………………….(1)}$$

Where: n = Sample size

z = Standard variate at a given confidence level (which is 1.96 at 95% confidence level; basing on table of area under normal curve)

p = Sample Proportion

$q = 1 - p$

N = Size of population (Number of farmer households)

e = Acceptable error (the precision)

Data for calculation of sample size were:

$z = 1.96$

$p = 0.1$

$q = 0.9$

$N = 3148$

$e = 5\%\ (0.05)$

Inserting data into the equation:

$$n = \frac{(1.96)^2 (0.1)(0.9)(3148)}{(0.05)^2 (3148) + (1.96)^2 (0.1)(0.9)} = 133$$

Thus, 133 respondents were interviewed during structured interviews.

In obtaining appropriate respondents from each village, the proportionate stratified sampling technique was used. The proportional allocation of households in every sampled village was conducted through proportionate formula by Kothari (2004), given as:

$$P_i = \frac{N_i}{N} n \quad \text{……………………………………………………… (2)}$$

Where, P_i = Proportional sample of each village

N_i = Number of household in each village

N = Total household forming the sampling frame

n = Sample size

Inserting data for each village in the equation above:

1. Ilela Village: $P_i = 1368/3148 \times 133 = 58$
2. Matekela Village: $P_i = 914/3148 \times 133 = 39$
3. Mitawa Village: $P_i = 866/3148 \times 133 = 36$

Total = 133

Thus, 58 heads of households were sampled from Ilela village, 39 from Matekela village and 36 from Mitawa village making a total of 133 respondents.

2.5. Data collection methods

Primary data were collected through questionnaires, interviews, observation and focus group discussions with the farmers, village leaders and extension officers. Secondary data were collected from the government reports, census reports, journal articles as well as library and web-based materials on the research topic. Also, 41 years climatic data from Tanzania Meteorological Agency (TMA) covering a period between 1980 and 2021 were used.

2.6. Data analysis and presentation

The data obtained from questionnaires, interviews, focus group discussions, field observations and meteorological 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 collected through focus group discussions, observation and in-depth interviews were examined and presented in summary form. Climatic data from Tanzania Meteorological Agency (TMA) were analyzed using Microsoft Office Excel to present patterns and trends of rainfall and temperature in the form of graphs. The analyzed data whether quantitatively or qualitatively were summarized and presented in the form of text, tables and figures.

3. Results and Discussions

3.1. Farming experiences and crops grown

Investigation on farmers' knowledge and experiences on farming was essential in this study. Issues of traditional farming practices and knowledge on climate change depend on ones' experience in farming activities. The exploration of this information formed an important basis in comparing meteorological data and farmer's experiences. Majority of the respondents (37.6%) reported to have involved in farming for about 30-39 years whereas some farmers reported to have engaged in the activity for more than 50 years as shown in Table 2. Further, the results in Table 2 indicates that majority of the respondents (79.7%) reported to engage in crop production, thus they are well informed on the techniques used in farming over the years and the environmental changes experienced. The findings signify that many farmers are well informed with farming activities. These results are in agreement with those of Oyewole (2012) who established that productivity is directly associated with years of cultivation experience.

Furthermore, the study investigated the main crops grown in the area whereas respondents mentioned to grow maize, wheat, beans, cassava, vegetables and coffee. However, maize was reported to be a staple crop in the study area (96.2% of the respondents). At national level it has been described that more than 80% of the Tanzanians consume maize, the crop is regarded as a major source of food (Lyimo *et al*., 2014). Mbinga district has large area for maize cultivation. The area has the opportunity to heighten maize production in the region and eventually contribute to national capacity in maize production, hence, reducing food insecurity (Utoga, 2022).

Table 2: Percentages on respondents' experiences on farming and crop types grown

Variables	**Responses in Percentage (%)**			
	Ilela n=58	Matekela n=39	Mitawa n=36	Total N=133
(a)Experiences in farming				
Between 1-19 years	3.4	12.8	19.4	10.5
Between 10-19 years	19	15.4	11.1	15.8
Between 20-29 years	24	20.5	16.7	21.1
Between 30-39 years	40	33.3	39	37.6
Between 40-49 years	8.6	15.4	8.3	10.5
More than 50 years	5	2.6	5.5	4.5
(b)Agricultural practices				
Crop production	75.8	82	83.4	79.7
Mixed Farming	24.2	18	16.6	20.3
(c) Crops grown				
Maize	96.5	94.8	97.2	96.2
Wheat	20.6	41	50	34.6
Beans	70.6	92.3	72.2	77.4
Coffee	36.2	48.7	36.1	39.8
Cassava	31	51.2	25	35.5
Vegetables	70	82	61.1	73.7

3.2. Traditional farming practices in the study area

Traditional cultivation is an old technique of farming which has been used since earlier periods. Over the years, there has been advancement in farming methods with the use of modern equipments making farming rapid and efficient. In spite of the increased contemporary farming techniques, few methods of traditional farming are still used in our days. Farming practices are inherently related to the magnitude of agricultural activities and the aim of farming, whether subsistence or commercial (Acheampong *et al*., 2021). In the current study, most of the farmers were smallholders whose primary goal is to obtain food. Various traditional farming practices were reported including Matengo pits (60%) in Mitawa village, (56%) in Ilela village and (51%) in Matekela village. Also, contour terracing was reported to be practised in the area whereby (24%) of the farmers in Ilela, (20%) in Matekela, and (17%) in Mitawa reported to practise contour terracing. The practice is described as the method of ploughing sloped land beside lines of steady elevation in order to conserve rainwater and to lessen soil losses from exterior erosion. The general orientation of the study area is covered by steep slopes which facilitate draining the top soils during rainy season, thus the practice of contour terracing leisurely the rate of erosion. Furthermore, about (20%) of the farmers reported to apply intercropping as a traditional farming technique. Intercropping is a practice of sowing more than one crop at the same time in the same piece of land. The method is useful in diverse arenas including; maximizing the use of resources, escalating yields and diversifying harvests on a single plot of land. Besides, intercropping creates biodiversity which are necessary towards pest management. Similar observations were also reported by other scholars (Jackson *et al.,* 2007; Mapunda; 2017; Bjornlund *et al.,* 2018) who observed that majority of the farmers engaged in various traditional farming techniques in their study areas. In the selected villages, Matengo pits predominated due to the nature of area as shown in Figure 1.

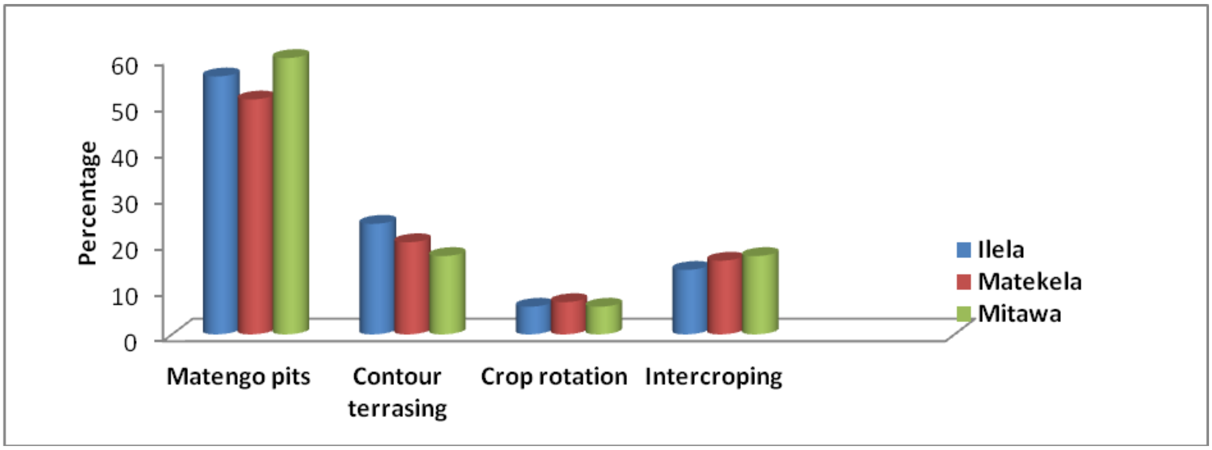

Figure 1: Traditional farming practices in the study area

3.3. Climate situation in the study area

Figure 2 indicates the perceived indicators of climate change in the study area. Majority (89%) of the respondents claimed to have observed changes of climate in their areas. Their perception of climate change based on their experiences of farming activities where they had noticed changes including rainfall variation, decrease in rainfall totals, changes in temperature, crop pests and disease, drought and water scarcity. The investigation of this information formed a considerable basis in comparing meteorological data and farmer's traditional knowledge. These results are also in agreement with a number of scholars (Malekela & Nyomora, 2019; Malekela & Yanda, 2021; Mkonda, 2022).

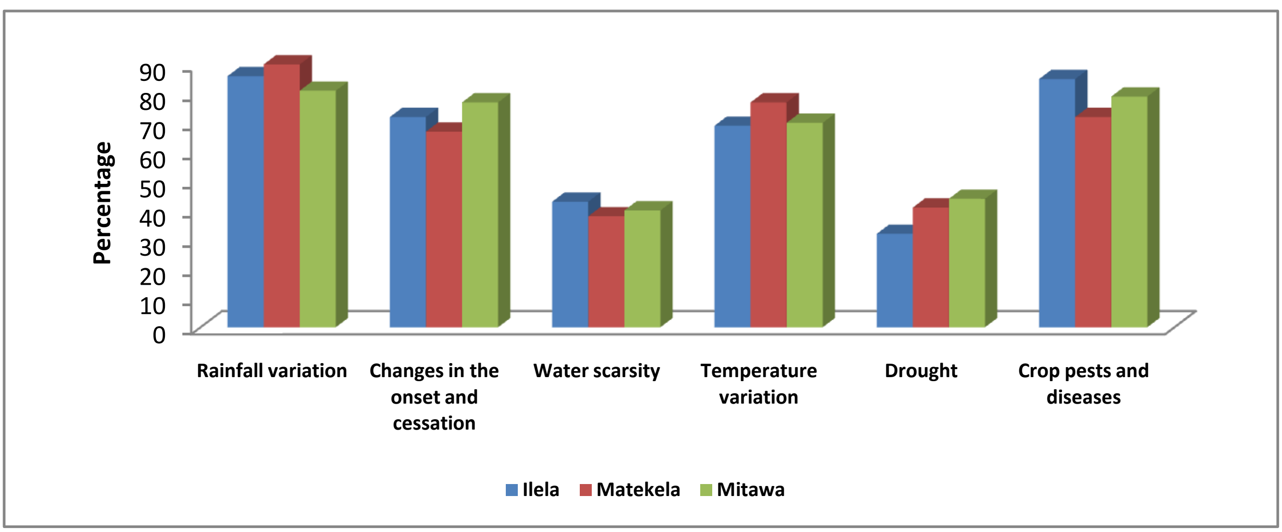

Figure 2: Perceived indicators of climate change in the study area

The climate situation in the study area is characterized by substantial deviation in rainfall totals; this is significantly evidenced by the results from the analysed meteorological data from TMA as indicated in Figure 3 which demonstrate for continual high variability in annual rainfall totals over the past 41 years (1980-2021). The 10-year trend line in the figure is not consistent throughout 41 years under study. The total annual rains had declined between 1301.6mm in 1980 to 901.5mm in 2021. The trend line shows that the average annual rainfall in the study area is decreasing at the rate of (P= -0.4204, R^2=0.0007) each year. Rainfall variations during the growing season affect crop production, particularly maize which is more susceptible to climate stress. The farmers highlighted to experience prolonged droughts in some months thus affecting maize production. Various climate models have confirmed that sub-Saharan Africa is the most vulnerable region to the impact of climate change due to low adaptive capacity (Copper 2002; IPCC, 2007; Speranza *et al.*, 2009)

Likewise, the area experience variations in temperatures. The meteorological data analyses revealed a temporal disparity of temperatures whereby in 1980 the minimum average temperature was 15.4°C; this had changed to 16.9°C in the year 2021. The maximum average temperatures had also varied from 29 °C to 28.2 °C between 1980 and 2021 respectively. Results for both minimum and maximum temperature indicate a significant increased trends (P= 0.0032, R^2=0.0016; P=0.0101, R^2=0.0575) respectively as indicated in Figure 3. Climate scientists have reported increase in global temperature by 1.1° Celsius (1.9° Fahrenheit) since 1880. The preponderance of the warming has transpired since 1975, at a rate of roughly 0.15 to 0.20°C per decade (Hansen, *et al.*, 2010; Lenssen *et al.*, 2019)

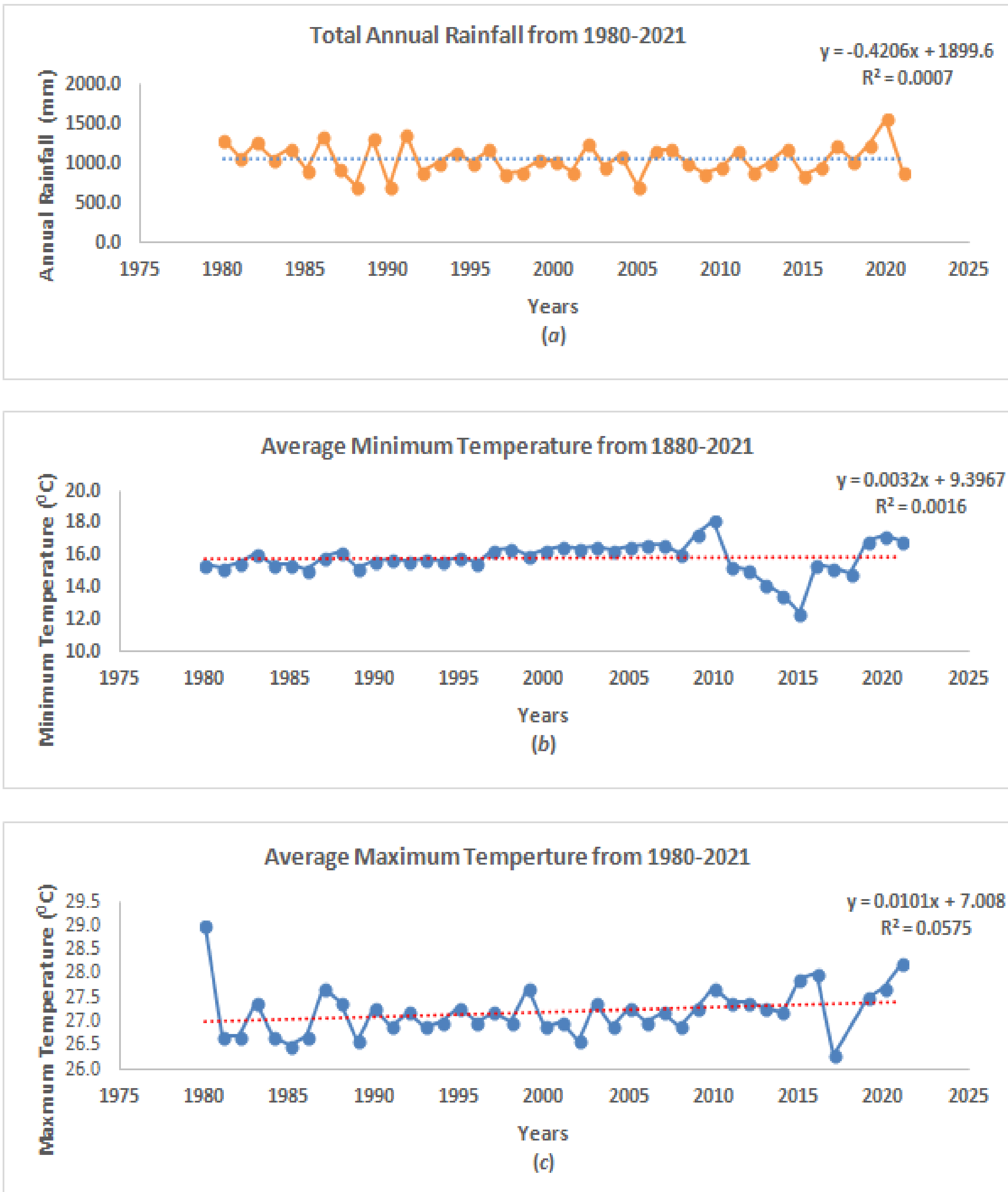

Figure 3: Total annual rainfall (a), minimum temperature (b) and maximum temperature (c).
Source: Tanzania Metrological Agency (2022).

Moreover, respondents also reported to perceive variation in the onset and cessation of rainfall as indicated in Figure 2. Farmers reported to have observed changes in the onset of rainfall whereas in the previous years, rainfall started in the early or mid November and ended during April or May, but in the recent years, there have been considerable changes. These observations reported by the farmers were evidenced from meteorological data indicated in Figure 4 which shows that over the past 41 years the area has experienced variations in rainfall during November and December which are essential months for farmers to grow their crops. Subsequently, rainfall cessation in the recent years is early than previous years. For instance in the year 1980 the total rainfall for April was 232.5mm this had dropped to 75.4mm in the year 2021. Variation in the onset and cessation of rainfall have tremendous impact on farming activities because famers fail to determine the accurate time to start farming activities. Consequently, these oscillations may eventually affect crop yields. In some occasions famers reported to experience changes in terms of the numbers of rain days whereby sometimes it rain for two to three days consecutively or it may rain for only one and stop for three to four days hence affecting seed germination. Similar observations were also reported by (Lobell and Burke, 2010; Kilembe et al., 2012) who observed variations in the onset and cessation of rainfall.

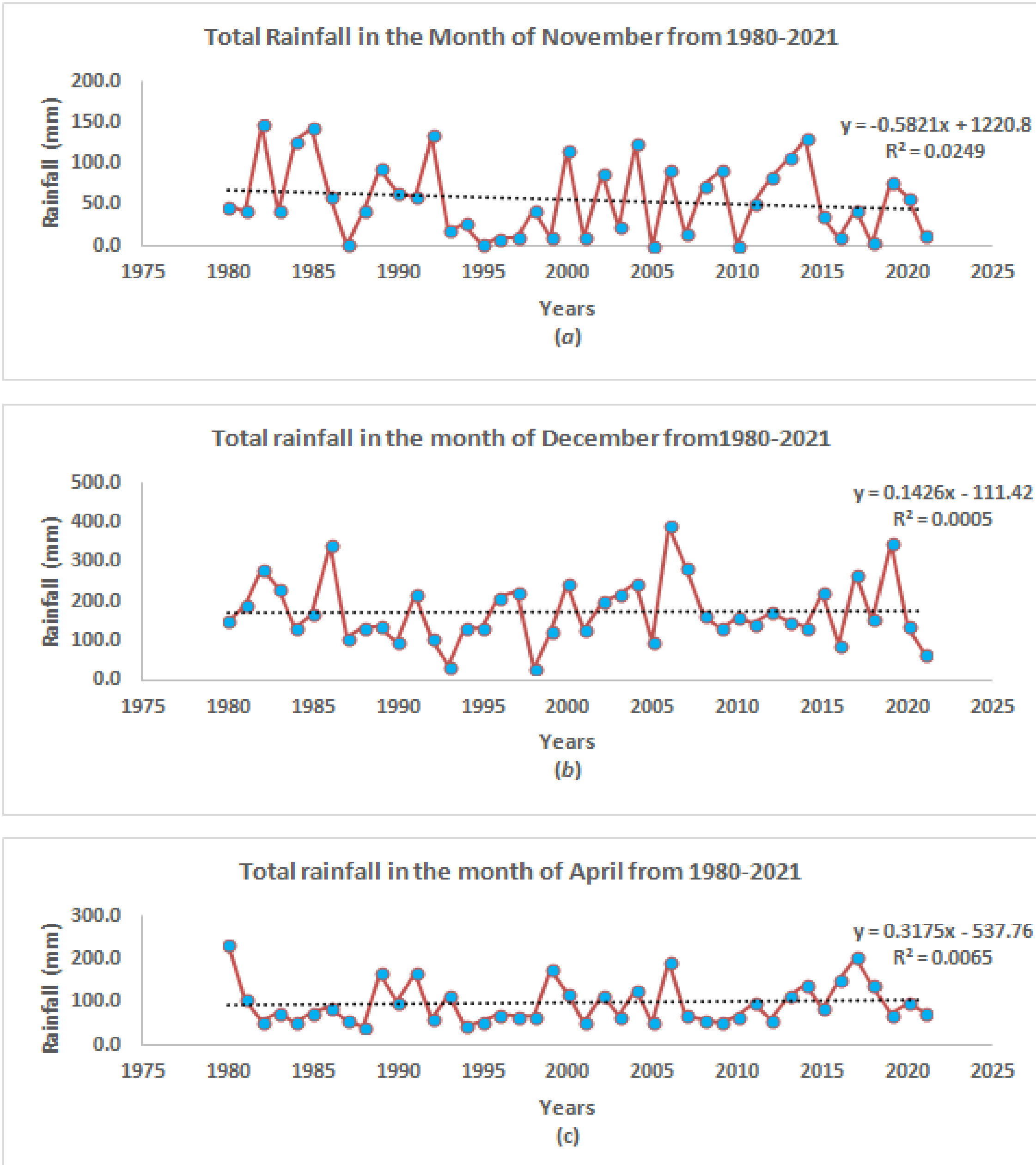

Figure 4: Total rainfall in the months of November (a), December (b) and April (c)
Source: Tanzania Metrological Agency (2022)

3.4. Usefulness of Matengo pits in adapting to climate change

The use of Matengo pits in the production of staple crops in Mbinga district started many years ago, Farmers applied this method as a traditional way of conserving soil moisture and avoiding soil erosion. In the beginning of 19^{th} century the method became a common practice in the study area (Malley *et al*., 2004). In the current study, the findings revealed that majority of the farmers (40%) reported to be involved in Matengo farming techniques for between 11 and 20 years, also 13% mentioned to have engaged in this practice for more than 30 years while 16% reported to have used Matengo pits for between 1 and 10 years. These results indicate the dominance of Matengo pits for several years with the intention of conserving soil as shown in Table 3.

Table 3: Numbers of years in which farmers involved in Matengo pits practices

Variables	Responses in Percentage (%)			
	Ilela n=58	Matekela n=39	Mitawa n=36	Total N=133
Years from using Matengo pits				
Between 1-10 years	16	15	16	16
Between 11-20 years	38	44	42	40
Between 21-30 years	31	33	28	31
More than 30 years	15	8	14	13

Over the years, Matengo pits have been considered as a method of soil conservation, but with the current climate change, Matengo pits are useful in not only conserving soil but also as a traditional method of adapting to climate change. Matengo pits can store moisture even after rain cessation thus enabling seed germination as shown in Figure 5. During this study, about 62% of the respondents reported that after the rain session water in pits can stay for 3 to 4 days. This duration can easily enable seed germination even if the rain stops for some days. Thus the method has been reported to be suitable than other traditional farming techniques. Furthermore, respondents were asked about harvest status from Matengo pits. The report indicates that 67% of the respondents obtain high amount of yields from Matengo pits than other farming techniques (Table 4). Many other scholars have documented that Matengo system is highly sustainable as it both protect soil and water. Besides, the high productivity of this system guarantee a stable food supply to the Matengo (Kato, 2001).

Table 4: Usefulness of Matengo pits in adapting to climate change

Variables	Responses in Percentage (%)			
	Ilela n=58	Matekela n=39	Mitawa n=36	Total N=133
(a) Moisture in Matengo pits after rain session				
Between 1- 2 days	7	8	17	10
Between 3-4 days	64	64	56	62
Between 5-6 days	26	26	19	24
More than 7 days	3	2	8	4
(c)Yields from Matengo pits				
Highest	9	18	14	13
High	67	59	75	67
Medium	21	15	8	16
Low	3	8	3	4
(c) Rate of seed germination				
Highest	71	77	73	73
High	22	20	22	22
Medium	7	3	5	5

Figure 5: Wheat germination in Matengo pits in the study area
Source: Survey data 2022

4. Conclusion and Recommendation

Traditional agricultural practices are undertaken in different parts of the world in spite of the advancement in science and technology. Mechanization in agriculture has not replaced traditional techniques. Farmers who espouse these practices enhance the fertility of their farmlands while obtaining the benefits of higher yields. The results of the current study revealed that farmers in the study area practised Matengo pits, intercropping, crop rotation and contour terracing. These practises aimed at conserving soils, however, the study focused on Matengo pits as a traditional method of adapting to the impact of climate change. It was revealed that the area experienced variations in rainfall totals, temperatures and changes in the onset and rainfall cessation as well as increased pests and diseases. The reported climate variations were confirmed with climatic data analyses from the Tanzania Metrological Agency covering a period from 1980-2021. The practices of Matengo pits have multiplier impact on both soil conservation and as an adaptation strategy to the impact of climate change. The practice enables seed germination even if the rain stops for some days. Moreover, the amount of yields were reported to be higher when the technique is used compared to where it is not. The study recommends for adoption of Matengo pits in other areas in this era of climate change and variability because the technique can store moisture even after rain cessation thus enabling crop growth.

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