

Experience of Smallholder Farmers on Climate Smart Agriculture on Soil Fertility and Moisture Conservation in Ludewa District, Tanzania

Digna Mlengule

University of Dar es Salaam, Tanzania; mlenguled@gmail.com

Citation: Mlengule, D. (2023) Experience of Smallholder Farmers on Climate Smart Agriculture on Soil Fertility and Moisture Conservation in Ludewa District, Tanzania. FARA Research Report Vol 7(37):474-487. <https://doi.org/10.59101/fr072337>

Abstract

The agriculture sector is vital for economic growth, poverty alleviation, and food security in developing countries. However, the economic losses from climate change impacts on agriculture are estimated to be higher yearly. Climate-smart agriculture offers opportunities to reduce climate change losses, build resilience, improve productivity and incomes, and mitigate climate change. This paper discusses the climate-smart agriculture on soil fertility and moisture conservation practiced Ludewa District, Njombe Region in the Southern Highlands of Tanzania.. Methods used in data collection were semi-structured interviews, key informant interviews, and observation. A total of 355 respondents were randomly selected for this study. The collected data were analysed using IBM Statistical Product and Service Solution; and content analysis. The study revealed that smallholder farmers have diverse climate-smart agriculture practices in soil fertility and moisture conservation. These include using organic manure, mulching, crop rotation, planting, and conserving plants that store water. However, they are practiced by few farmers. This is due to lack of the requisite education, awareness, information and training to adopt to climate-smart agriculture practices. It is concluded that climate-smart agriculture practices are essential for smallholder farmers to reduce their vulnerability to climate change and variability. This calls for strengthening the sustainability of smart climate agriculture through ongoing capacity building, provision of extension services, and incentives to smallholder farmers for practicing them.

Keywords: Smallholder farmers, climate-smart agriculture, climate vulnerability, soil fertility and moisture conservation.

1. Introduction

Climate change affect agricultural production in direct and indirect paths. Crop development is accelerated by the increase in mean temperatures directly, while the change in seasonal precipitation amounts and increasing evaporative demand indirectly lead to drought stress for crops [1;2;3; 4]. Increase in temperatures shorten the crop cycle and phenological stages, thus reducing crop production. While alteration of precipitation pattern affect water availability for crops hence less crop yield. Therefore, global climate change has a severe impacts on crop production and inflicts varied constraints on agricultural systems, particularly in water constrained environments [1;3]. The negative effects of climate change are higher in developing countries than developed countries since most people in developing countries depend much on natural resources that are sensitive to climate, have limited skills and ability to mitigate climate hazards [5]. According to Intergovernmental Panel on Climate Change [3], Africa is identified as the most vulnerable to the effects of climate change and variability mainly because of its high economic dependency on climate-related activities and low adaptive capacity. This low adaptive capacity is linked to inadequate developed government structures, weak economies and weak institutions [6]. Hence, the effects of climate change in the sub-Saharan countries and its population are of high risk to flooding, infrastructure damages, health problems, food shortages, drought conditions and rural urban migration as a result of rural livelihood degradation [5].

In the Sub-Sahara Africa, agriculture is a significant contributor to its economy acting as a backbone to social development [7]. Further, [7] describes agriculture as the main contributor to livelihoods in the rural sub-Saharan communities as it employs more than half of its population. However, the agricultural sector in Sub-Saharan Africa is vulnerable to climate change with approximately 96% of the overall population practicing rain-fed agriculture [7]. Also smallholder farmers are challenged by inadequate resources, poor infrastructure and limited access to information. Many smallholder farmers in Africa are facing poverty, food insecurity, the degradation of water resources and local land, and increasing climate variability [3]. Most of these vulnerable smallholder farmers depends on agriculture both for nutrition and food security and at the same time responding to climate change [8]. The core challenge is to increase the resilience of farming systems, livelihoods and sustainably improve food production [9]. This means to transform the production systems by adopting a new perspective on agriculture and introducing low emission and more climate-resilient agricultural practices with promotion of suitable incentive mechanisms for smallholder farmers with appropriate programmes and policies. Climate Smart Agriculture (CSA) is one of the approaches for transforming and reorienting agricultural development under the realities of climate change [6].

Just like other developing countries, there has been an increasing attention to adaptation of Climate-Smart Agriculture (CSA) in Tanzania as a way to cope with climate change [10]. CSA are essential to support farming communities to achieve adapting to climate change, reduce the greenhouse gas emissions, and improve food security through building the resilience of agricultural livelihoods and ecosystems [9]. Among the important ecosystems for agriculture are soil and water. In Tanzania, the government has responded to climate change challenges on food and nutrition security by undertaking various effort at the national level, including the development of the National Climate Change Strategy (2012) and the National Climate-Smart Agriculture programme (2015-2025). These recently developed programs aims to accelerate the uptake of CSA practices by the smallholder farmers so as to increase climate resilience in the agriculture sector and productivity, but also to reduce greenhouse gases emissions in the country [11].

Since the adverse effects of climate change are locally experienced, CSA practices need to be tailored to the particular social-economic conditions, specific characteristics of local farming systems and farmers requirements [10]. In the past, planning and policies for adaptation were addressed at the national level whereas in the present, the focus has proliferated into the local level [12]. This focus has shifted due to a number of reasons, one being 'adaptation is local' as defined by many literature [12]. This is due to the fact that climate change effects varies geographically thus the need for place-based approaches to the analysis of climate vulnerability and adaptation.

Different stakeholders are involved to implement CSA. They include international organisation like FAO, UNDP and WB; government institutions; Civil Society Organisations such as TFCG, ACTION AID, MJUMITA, TOAM and MVIWATA and individual people. Among the promoted CSA are tree planting and agroforestry, improved cooking stoves, soil and water conservation and diversification practices. Despite the CSA practices presenting several potential environmental and economic benefits to smallholder farmers, its adoption among Tanzania smallholder farmers is low [10]. Low capacity of farmers to contribute resources to adoption of CSA is one of the major challenge. Other challenge is lack of involvement of smallholder farmers in the formulation process, unwillingness and inadequate understanding of climate change related by-laws, policies and initiatives [12]. From this background this paper documents CSA climate smart agriculture on soil fertility and moisture conservation practised in Ludewa District, Njombe Region in the Southern Highlands of Tanzania. This is fundamental because climate change is undermining sustainable agricultural development. There is the need for scaling up

CSA practices to all smallholder farmers to increase their adaptive capacity to climate change vulnerability.

2. Conceptualization of climate change and smart climate agriculture

The impact of climate change on crop production and food security in Africa is evident, therefore, climate change is increasingly becoming a severe food insecurity threat [1]. [18] depicted that the number of food-insecure people grew from 90 million in 1970 to 225 million in 2008; by 2015, it was estimated to be 325 million. In sub-Saharan Africa, yield potential for food crops is projected to decline due to increased marginal areas for agriculture and changes of growing seasons [18, 6] Loss of forest cover exposes soil to erosion hence reduction of fertility and resulting in low agricultural production [19]. Growing each crop requires different climate and environmental conditions [16]. Therefore, change in climate alters the boundary of certain crops. For example, most Southern African maize and wheat crops already experience drought stress. An increase of 2°C in average temperatures is projected to shrink coffee production in Uganda [19]. However, a change in crop boundary may be a crisis to some areas and an opportunity for other areas [1]. That means climate variability and changes have both positive and negative impacts.

Farmers are exposed to changes in rainfall patterns, temperature variation, and extreme events like floods and droughts [21, 23]. Changes in rainfall patterns such as intensity, time of onset and offset make it difficult for farmers to decide what and when to plant. Increased temperature shifts growing seasons and changes the geographical distribution of pests and diseases which harm humans, plants and animals [21]. It contributes to the disruption of agricultural yields and productivity hence low income to farmers and food insecurity. Other than climatic change farmers' sensitivity increases due to social, economic, political and cultural constraints that determine their capacity to cope with external stresses [24]. Several factors compound smallholder farmers' vulnerability to changes in climate. The factors are not limited to poverty, weak institutions, limited infrastructure, inadequate technology and access to information, and limited resources [23]. Because of poverty farmers cultivate very small land with limited application of inputs [23, 25]. This leads to low crop yields with no surplus.

In some cases yields are insufficient even to meet household needs. Moreover, most smallholder farmers live in remote areas; therefore, infrastructures like roads and markets are limited [25]. In such situations, farmers cannot sell their goods to the market and cannot access farm inputs and other related information. The capacity to adapt has a serious influence on farmers' vulnerability to climate variability and change [20]. Therefore, climate adaptation plans should consider how sensitive farmers and resources are to changes in climate.

Adaptation may occur at several scales, from individual farmers to national and international levels involving interrelated but different actors [32; 15; 19]. At local level, adaptations depend on local circumstances but decisions are driven by internal (income loss) and external forces (macro-economic policy, institutional frameworks) [33]. Adaptation to climate change also takes place through a dynamic political, social, economic, biophysical and technological context [34; 33; 35]. These dynamics vary over time, space and sector and influence the system's capacity to adjust. In this case, societies' adaptive capacities to deal with climate change are not equally distributed, across countries and within individuals in societies [36].

[26] stated that the capacity of farming systems to adapt to changing climate depends on natural resources endowment and associated economic, social and political condition. This means effective adaptation approach should address a range of environmental stresses. Improving the capacity of the poor to adapt involves adopting innovation that builds on their experience and knowledge [27]. [38] argue that past and ongoing adaptation can be used to gain insight into change process and help identify their possible characteristics and constraints. These experiences and knowledge are crucial for planning successful adaptation strategies. So, more research needs to be done to ensure clear understanding of the smallholder farmers' experience on adaptation to climate change. Farmers are considered to be the most vulnerable group to the risks and impacts of changing climate [33, 35]. Though they are vulnerable, they are the most resourceful regarding knowledge for adapting to climate change [39].

Climate-smart agriculture is vital for sustainable agriculture. It gives multidimensional paths to tackle climate change [6]. It is an integrated approach for developing technical, policy, and investment conditions to achieve sustainable agricultural development for food security under climate change. Climate-smart agriculture emphasizes

developing technical, political, and financial conditions to achieve sustainable development goals [6]. Three pillars build CSA: a sustainable increase of agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and mitigation [6, 41].

Different authors have discussed the need of climate smart agriculture practices. [12] Studied Climate Smart Agriculture practices in Southeast Asia. [12] Explain that, despite overall trend of positive growth in Southeast Asia, it remains highly vulnerable to climate change as noted through increased water stress, warming trends, droughts, floods and temperature extremes across the region and negatively affecting food production and food security on the livelihoods of smallholder farmers. Based on the observation, [12] commented that, the adaptation of CSA is a key priority for building agriculture resilience in Southeast Asia. [42] Assessed the adaptation strategies of smallholder farmers using CSA in Rejosari, Indonesia. The results revealed that smallholder farmers in Rejosari implemented rain fed agriculture and experience reduced crop yield, drought, and pest and disease outbreaks. In this regard, smallholder farmers were introduced to CSA practices to reduce vulnerability to climate change. These reasons are similar to that of [43] who assessed the adoption of CSA technologies and determinants of adaptation strategies. [43] commented that organic manure, crop rotation and crop diversification were the most popular CSA practices among the sampled farmers. Therefore, CSA was proposed to reorient and transform the agriculture system to support vulnerable smallholder farmers.

According to [44], in his study which addresses the role of CSA on improving resilience and productivity of smallholder farming in southern Africa, he identifies major characteristics which impulse the need for CSA. [44] commented that, limited skills and equipment required for disaster management, over reliance of livelihoods on agriculture, weak institutional capacity, scarcity of capital for implementing adoption measures and climate variability worsen the vulnerability of smallholder farmers. However, adaptation research identified CSA as an appropriate strategy to ensure smallholder farming systems withstand the delirious effects of climate change and variability. [45] investigated Climate Smart Agriculture used among smallholder farmers to cope with variability and climate change in Mozambique. [45] observed that most smallholder farmers earn their livelihood mostly from climate sensitive rain-fed agriculture.

Consequently, the yields are subjected to weather driven fluctuations and are generally low due to an increase of average temperature, shift in distribution of daily temperature and change in rainfall. However, because many smallholder farmers lack the options to step out of agriculture, the agriculture sector will remain important for their livelihood. Thus, CSA practices are promoted to assist smallholder farmers in vulnerable communities.

Different climate smart agriculture practices are presented by [6]. Fig.1. They include climate services and weather insurance, diversification, mitigation, community management of resources and capacity building. The adoption of these climate smart agriculture practices depend on different factors. The factors may include slope of the plot, soil organic carbon content, food security status, mean monthly precipitation and mean monthly temperature, literacy index, access to agricultural and climate information, credit and assets endowment. [41] have pinpointed that population growth increases demand for food and water thus creating scarcity of these resources coupled with climate change the situation is even worse. Climate-smart agriculture is a better option to manage soil and water for sustainable food production while at the same time reducing emission of greenhouse gases. [6] identified soil management practices such as mixed cropping, intercropping, and organic farming, conservation tillage, residue management, and mulching and agro forestry. They argue that integrated farming systems protect the agro-ecosystems and provide food, fuel, and timber. Also the integrated crop and soil management systems is argued to increase soil carbon sequestration and help to combat climate change. However, adoption of them is rare by most of the smallholder farmers. This calls for more discussion to scale up smallholder farmers' adoption of climate smart agriculture. This paper documents the experience of climate smart agriculture as practiced by smallholder farmers in Ludewa District Southern Highland, Tanzania.

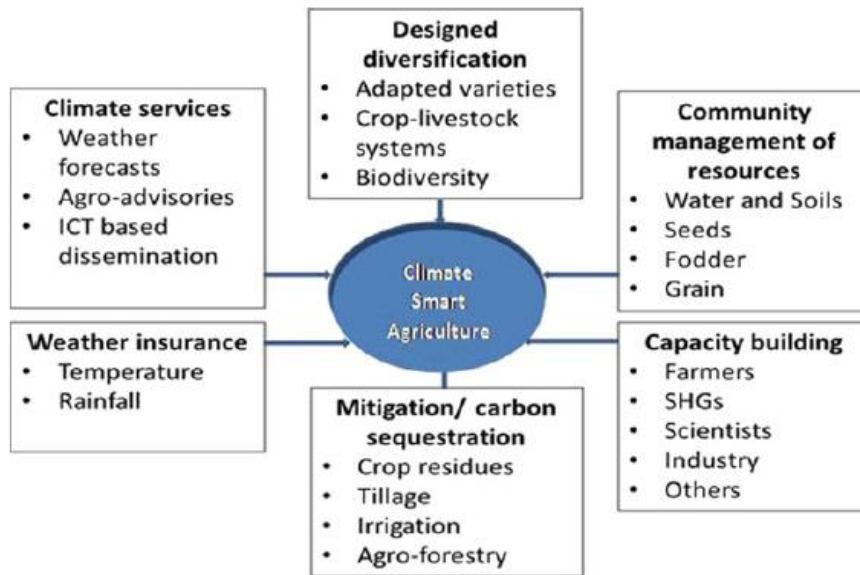


Fig 1. Different options for climate smart agriculture

Source: [6]

3. Materials and Methods

The study was conducted in Ludewa District in the Southern Highlands of Tanzania. Ludewa district is among the four districts of Njombe region. It is located approximately 34°10'E - 35°21'E and 09°30'S - 10°36'S in Njombe region, in South West Tanzania along Lake Nyasa which is in East Africa Rift Valley System [46]. It lies between 500m and 2800m above sea level. The ethnic groups in this district are mainly Pangwa, Manda and Kisi. Ludewa district is characterised by tropical climate regulated by altitude [47]. The area has a single rain season from November to May and it is dry during the rest of the period. It is divided into three agro-ecological zones; which are the highlands zone; the Midlands zone and the Lowland zone [47]. These zones are differentiated by altitude, rainfall, temperature and soil. Annual rainfall ranges between 900mm to 1600mm. Whereby the highlands receive annual rainfall that range between 1000mm-1600mm; midlands annual average rainfall is 1200mm while the lowlands annual average rainfall is 900mm. Due to rainfall and temperature variations there is some difference on crops grown and animals kept from one agro-ecological zone to another though some crops and animals are found in all zones.

The researcher employed both quantitative and qualitative methods. Three sampling techniques were employed: stratified, simple random and purposive sampling. Stratified and purposive sampling were used to select wards and villages to ensure that each agro-ecological zone was represented. The villages selected were as follow: Madope and Shaurimoyo (Highlands), Ludewa Rural, Madunda and Luana (midlands) and Nkomang'ombe, Mbongo and Ilela (lowlands). The total households for the sampled villages were 4,190. To get the sample size for the study, the number of the household (4190) was entered in the sample size calculation table developed by The [48]. Then the desired confidence level of 95.0% and margin error of 0.05 was set which gave a sample size of 355 households. The sample size was about 8.5% of the total household of the selected villages. [49] states that sample size should be at least 5% of the target population. Probability proportional to size was used to get the proportion sample size for each village. To obtain heads of households for the study simple random method was employed.

The sampled list of households in the eight villages was obtained with the help of ward executive officer and villages' chairperson.

Purposive sampling was used to obtain elders and officials for in-depth interview. These included two farmers (male and female) with long experience in farming (with age above 50 years), in each village that made 16 elders. In addition, four district officials were included in in-depth interview (agricultural officer, water resources officer, natural resources officer, and health officer)

A varieties of methods were used to obtain information and various stakeholders were involved. The methods of data collection included semi-structured interview, in-depth interviews, focus group discussion and observation. Through these methods it was possible to uncover knowledge used by the smallholder farmers in conservation of soil and moisture. Semi-structured interview used questioner with close and open ended questions to collect data. In-depth interview and focus group discussion used guiding questions to solicit information. Observation methods was used to complement semi-structured and in-depth interview methods whereby some picture were taken that were relevant for soil and moisture conservation. The data collected through the questionnaire, were later coded and cleaned. The coded and cleaned data were analysed by using IBM Statistical Product and Service Solution version 20. Descriptive statistics such as frequencies and percentages of household responses on different issues were used in the analysis. Qualitative data from in-depth interviews were analysed by using content analysis method. This involved extracting information from narratives to obtain categories of emerging themes.

4. Results and Discussion

This section presents the results on soil and water conservation practiced by smallholder farmers in Ludewa district

4.1 Smallholder farmers practices on soil fertility improvement and conservation

Soil with good quality is vital for sustaining biological productivity, maintain the environment and promotes plant and animal health hence sustenance of socioeconomic system. The finding of this study indicated that smallholder farmers in Ludewa District practiced different methods to improve soil fertility. These included organic manure land fallow, crop rotation, inorganic fertiliser and burning plant residues. This are shown in table 1 below.

Table 1 Practices in soil fertility improvement

Methods	Frequency	Percent
Organic manure	180	38.3
Land fallow	125	26.6
Crop rotation	72	15.3
Inorganic fertilizers	50	10.6
None	40	8.5
Burning of plant residues	3	0.6
Total	470	100.0

The use of organic manure was by 38.3 percent only. Organic manure helps to maintain soil fertility as well as to store soil moisture both important for growth of crops. Through the focus group discussion with farmers it was shown that organic manure was of different type such as farmyard manure compost manure, and green manure. Farm yard manure and compost manure were mainly used than green manure. Farmyard manure was from animals kept such as pig, cattle, sheep, goat, poultry and *simbilisi*

(guinea pig). Through the focus group discussion it was revealed that organic fertiliser was mainly used in garden and in small farm. The quote below show that farmers use organic manure from animals to improve soil fertility as it was revealed by one female aged 54 years through in-depth interview at Nkomang'ombe.

"We use manure from poultry, goat, cow and bat in vegetable gardens and maize farm. Manure from bat is very good in vegetable production but is difficult to get because the bats are found in only two government buildings. Therefore only one sack may be found if one farmer goes to collect"

Farmyard manure was used in small areas because in most cases cattle were kept in outdoor grazing system. This made it difficult for farmer to collect the manure. Also not all farmers had cattle. So they were only able to collect manure from pigs, poultry, goats and guinea pig which satisfy only the vegetable garden. In the lowlands agro-ecological zone even manure from pig was difficult to collect because they were left out as cattle. Plate 1 shows observed pigs in outdoor grazing system in Nkomang'ombe village. This practice made it difficult for farmers to collect manures for their farm. So lack of awareness on indoor animal keeping might be a major reason for continuing with outdoor grazing hence inefficiency use of farm yard manure. Organic fertilizer reduces losses of nutrients by regulating the crop demand with soil nutrient availability [6].



Plate 1. Free range of pigs in Nkomag'ombe village

The composite manure was made by cutting vegetation then they were burned or buried in ridges *matema* (slash and burn practice). Through in-depth interviews with informants it was revealed that slash and burn was the main method used to improve soil fertility. According to them by doing so they get more production because they believe that ashes add soil fertility. However, the practice was associated with great loss of forests. Since farmers were expected to find virgine land each year or after two years for crop production as slash and burn does not maintain soil fertility for long time. The practice contributes to killing of living organisms responsible for organic matter decomposition thus just after a short time the soil losses its fertility. As time goes the arable lands become bare. The process also exposes the land to rain water runoff and wind thus increases soil erosion. All these lead to loss of soil fertility. Not only that but also, loss of forests reduces the carbon sink thus increasing global warming. The study by [50] analysed land use cover change, the result indicated that there was decline of area covered by woodland by 40% in 1979 to 15% in 2002 as deforestation increased. Therefore, a total of 12,135 ha of forest were cleared between 1979 and 2002 making a loss of 528 ha per year. Therefore, slash and burn was not

beneficial to long run agriculture and sustainable forestry for carbon sequestration. Given the population increase large areas of vegetation were cleared.

Slash and burn was followed by land fallow by some farmers. Whereby 26.6 % of heads of households used it as a means to maintain soil fertility. Other than conserving soil fertility this strategy increases carbon sink because it allows forest to regenerate. However, population increase was reducing its sustainability. This was also found by [51] in Sahel that the practice of land fallow has been reduced and in some area it does not exist due to the growth of population which increases demand of land. [10] has shown that high population growth increases pressure on agricultural production and natural resource hence increasing the challenge of poverty reduction. It was revealed through in-depth interview that the period of one or two years farms were left to regenerate was shorter and the majority do not practice it due to shortage of land.

Crop rotation was practised by few farmers in the highlands and in midlands. Smallholder farmers changed types of crops from year to year from one farm to another farm. For example, if the farm in that year was planted with maize the next year potatoes would be or after they had harvested potatoes they would plant wheat or peas. This was done to improve soil fertility other than practicing monoculture.

Through focus group discussion it was revealed that in the lowlands smallholder farmers preferred intercropping. Intercropping was done to cope with climate variability as shown in the quotation below from one of the participants of focus group discussion in Mbongo village. In this intercropping system farmers planted more than one crop in the same field such as cassava and maize. Other than adapting to climate variability intercropping was done to solve land shortage and improve soil fertility. [52] has stated that crop rotation has proved success in past years by our ancestors. [10] emphasizes that intercropping and crop rotation motivates farmers because they increase income generation hence adaptive capacity. Therefore, farmers should be encouraged to apply them for sustainable crop production.

“In our place many farmers practise intercropping whereby different crops are mixed in one farm. Very few farmers practice mono-cropping. For example maize is normally mixed with cassava. Intercropping helps to cope with rainfall variation, improve soil fertility particularly when mixed with leguminous crops also solves land shortage problem”

Inorganic fertiliser was used by few farmers who were able to afford fertiliser prices. Through in-depth interview it was revealed that the fertiliser price ranged between 50,000 to 90,000 Tanzania shillings depending on the type of fertiliser. In the lowland it was revealed during the group interview that there was low awareness on the use of both organic and inorganic fertiliser. It was reported that they did not use fertiliser in their farming activities. Instead land fallow and burning of plant residue were the ways used to improve soil fertility. Inorganic fertiliser was used by few farmers who were able to afford fertiliser prices. During in-depth interview it was revealed that the fertiliser price ranged between TZS 50,000 to 90,000 depending on the type of fertiliser. In the lowland it was revealed that there was little awareness on the use of both organic and inorganic fertiliser. In general the use of fertilisers to improve soil fertility was minimal thus adding to low production. In focus group discussion it was revealed that inaccessibility and high prices of fertilisers made farmers to follow fertile arable land through slash and burn even along water sources. Hence environmental degradation (see Quotation below).

“One of the major constraints to farming is poverty. This causes farmers to look for fertile land because they are unable to afford farm inputs. This increases forests depletion due to search for fertile land. Even though the government gives farm inputs subsidies yet farmers are unable to contribute little money they are supposed to pay. Therefore, most farmers normally get incomplete package of farm inputs”

4.2 Smallholder farmers Practices on soil moisture conservation

Other than soil improvement farmers in Ludewa also use different ways to conserve soil moisture. The ways are depicted in Table 2. They include conservation of plants that store moisture, use of water channels and terraces, irrigation, mulching and organic manure. However, 59.7% of the respondents reported to do nothing in conserving soil moisture.

Table 2. Response on knowledge on soil moisture conservation

Soil moisture Conservation methods	Frequency	Percent
Nothing done	212	59.7
No response	77	21.7
Conserving plant species that store water	17	4.8
Irrigating	16	4.5
Making water channels and terraces	16	4.5
Mulching	13	3.6
Use of organic manure	4	1.1
Total	355	100.0

Only 17 (4.8%) respondents acknowledged to conserve plant species that store water. During focus group discussion participants mentioned those trees to included trees such as *mivengi* (*syzygium cordatum*), *midobole* (*Hagenia abyssinica*), *mavangalala* (*Musa sp/Ensete ventricosum*) and *mahimbi* (*Colcasia esculenta*). Some of the reported trees are shown in Plate 2 a, b and c. These vegetations were noted to have double impact. *Mivengi* other than conserving water also provided edible fruits while *midobole* provided timber and *mahimbi* (yams) provided food.



(a)



(b)



(c)

Plates 2: Reported plants that conserve soil and water (a) Mahimbi/yam (*Colcasia esculenta*) at Ludewa Village (b) Mivengi trees (*Syzygium cordatum*) at Madunda Village (c) Midobole (*Hagenia abyssinica*) trees (in the background) at Madope village

The mentioned plants were reported to exist in most of the water sources in the past years and water was available in abundant. Current there has been disappearance of these plant species due to human activities mainly agricultural activities. So have resulted in water reduction and some streams and spring have disappeared. Lowland rivers such as Mchuchuma and Masimavalafu were revealed to change from perennial to seasonal while levels of several rivers such as Nyakalai, Nyatulua, Nyakapela, Mabwabwa and Mhumbi in Nkomang'ombe have decreased and some streams have dried completely. In

midland zone rivers like Itepetali and Mpungu were reported to dry. In highland zone River Maheda was said to dry while Lugarawa, Luyenze, Lupali, Kigima, Idete, Lukasi and Luhanga were reported to decrease their water levels as years go by. In group discussion in Mbongo village it was explained that the loss of vegetation in upper and middle of the River Nchuchuma led to decrease of water level. Loss of vegetation affects rainfall availability, siltation of water sources, run-off, and infiltration. The study by [53] in Mara found that there was a positive relation between land use changes and rainfall and water sources reliability. The decrease of vegetation cover, changes rainfall water run-off and water infiltration [54]. With the absence of vegetation, run-off is speeded up thus reducing the percolation of water into the soil to feed springs and sub-surface aquifer; hence reducing the level and flow of water in streams and rivers. This have impact to different water use including agriculture production.

Irrigation was practiced by few household 4.5%. Irrigation practiced was mainly traditional whereby farmers used bucket irrigation method. Few farmers reported to use sprinklers and *money maker* pumps irrigation. In this case farmers were able to produce some crops from small areas and what was produced contributed to food availability. What was produced was sufficient for household consumption purposes. Among the eight villages studied only one practiced sprinkler irrigation (Madope) where Irish potatoes were grown and the rest practiced *vinyunyu* (surface irrigation in wet valleys) where sometimes they used buckets to irrigate crops.

Secondary data indicate that the estimated potential area for irrigation in Ludewa District was about 4090 hectares and area under irrigation was 252ha (6.2%) mainly traditional. About 3838 (93.8%) hectares were yet to be developed. If developed could help farmers to increase their income in case of rainfall shortfall particularly in lowland agro-ecological zone where drought was the main problem due to its semi-arid condition. It was revealed by agricultural officer that there were two improved irrigation schemes. One was found in Lifua where paddy was produced and the other was in Mkiu where maize, Irish potatoes and vegetables were irrigated. However, Lifua scheme was recurrent affected by drought. Inadequate capital to establish irrigation schemes in Ludewa district make irrigation farming uncommon despite the big potential area for irrigation. Agricultural census of 2007/08 indicates low development of irrigation in Ludewa whereby only 9% of interviewed household were engaged in irrigation farming. Low development irrigation status is a national wide problem. According to [55] irrigation potential in Tanzania is 29.4 million hectares. Among these 2.3 is high potential, 4.8 is medium potential and 22.3 is low potential. However, only 1% of the potential irrigation area is developed. Less area is developed for irrigation over the country due to lack of irrigation facilities. [56;57; 58] argued that there is underdevelopment of irrigation potentials in Tanzania by both private and government institutions. [16] argued that most subsistent farmers in Africa rely on rainfall thus small changes in rainfall have great impact to them. This is the case with Ludewa lowland agro-ecological zone where farmers are normally affected by drought and flood. Lack of irrigation facilities due to poverty undermine farmers' efforts to adapt to changes in climate [58]. Therefore, both private and government institutions need to support farmers financially to develop irrigation scheme and provide skills on how to use water efficiently.

Other than irrigation mulching and organic manure were the common ways of conserving soil moisture but were mainly used in vegetable garden, except in Madunda where they were used in coffee production. Plate 3 shows maize plant remains used to make mulching in a coffee farm in Madunda village. Other than conserving soil moisture mulching also improves soil fertility. In Madope Village mulching was used to prevent tea from drying from frost as well as vegetables. The only difference is the way grasses were put. In preventing frost to dry crops, grasses were put above the crop while in conserving moisture grasses were layered down in soil surface. Similar findings has been shown [59] that application of organic manure and mulching to crops under deficit irrigation lessened the effect of water stress hence increase yield.



Plate 3. Mulching practice in coffee farm at Madunda village

For example covering ground surface improves soil surface condition, organic content and porosity. In turn these influence infiltration, water storage hence water available for plant growth. Mulching other than conserving soil moisture also moderates temperatures, suppress diseases and pests. Mulching is a good strategy though application in large farm was not easily by farmers in Ludewa District. A study done by [51] in the Sahel observed that farmers have been practicing zero tilling, organic farming, mulching, agro-forestry and fallowing which are important ways of conserving soil fertility and moisture that increase crop yields. Some of these strategies are adaptation and mitigation that helps in creating carbon sink. Contrary [60], [51] observed that farmers have sufficient strategies to combat climate change but they are not being applied in effective ways.

5. Conclusion

From the above findings few farmers practiced climate smart agriculture to conserve soil and water. This implies that lack of awareness or lack of education made most farmers to do nothing on conserving soil fertility and moisture. . It is concluded that climate-smart agriculture practices are essential for smallholder farmers to reduce their vulnerability to climate change and variability. This calls for strengthening the sustainability of smart climate agriculture through ongoing capacity building, provision of extension services, and incentives to smallholder farmers for practicing them. Smallholder farmers need to be made aware off the good practices for soil and water conservation practices. This can be done by building their capacity through both formal and informal institutions guided by the national policies and strategies with regard to climate change adaptation and mitigations.

Acknowledgement: This paper is an output of my PhD Thesis. Therefore I acknowledge the University of Dar es Salaam for funding my research through UDSM/PITRO Supported Human Resources Capacity Development Scholarship

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable.

Conflicts of Interest: The author declare no conflict of interest.

References

1. IPCC, Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 200; 104 pp.

2. IPCC, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 2012; 582 pp
3. IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 2014; 151 pp.
4. IPCC, *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Lösschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. 2022, In Press.
5. Serdeczny, O., Adams, S., Baarsch, F., & Coumou, D., *Climate change impacts in Sub-Saharan Africa: From Physical Changes to Their Social Repercussions..* Berlin Heidelberg: Springer, 2015, 8: Vol. 15
6. Bhattacharyya, P.; Pathak, H.; Pal, S *Climate Smart Agriculture Concepts, Challenges, and Opportunities 2020*; Springer Nature Singapore Pte Ltd. <https://doi.org/10.1007/978-981-15-9132-7>
7. World Bank, Agriculture in Africa – Telling myths from facts. *A synthesis. Food Policy*, 2015; 67, 1–11.
8. Mlengule, D. (2019) Smallholder Farmers’ Knowledge in Adaptation to Climate Variability Experience from Ludewa District, Published in Tanzania Journal of Population Studies and Development. University of Dar es Salaam, 2019; Vol. 26 No 2
9. Food and Agricultural Organization of the United Nation, (2013) Climate Smart Agriculture Source book; 2013 Retrieved 2nd April, 2014 from www.fao.org/publication
10. Food and Agricultural Organization of the United Nation (FAO), Climate-Smart Agriculture Guideline for the United Republic of Tanzania: A country–driven response to climate change, food and nutrition insecurity; Policy Brief, 2017
11. United Republic of Tanzania (URT) National Climate Change Response Strategy (2021-2026). Vice President’s Office, Division of Environment, Government Printer, Dodoma. Tanzania, 2021
12. Chandra, A., Dargusch, P., McNamara, K., Caspe, A., & Dalabajan, A Study of Climate-Smart Farming Practices and Climate-resiliency Field Schools in Mindanao, the Philippines. *World Development*, 2017; 98(C), 214–230.
13. United Republic of Tanzania **National Adaptation Programme of Action** Division of Environment, Dar es Salaam Tanzania 2007,
14. International Institute for Sustainable Development (IISD), (2010) *Community Based Adaptation to Climate Change Bulletin; A Summary of the Fourth International Conference on Community Based Adaptation to Climate Change, 2010*; 135 (3). Retrieved 19th March, 2011 from www.iisd.ca/yimb/climate/cba4/
15. Below, I., Artner, A., Siebert, R. and Sieber; *Micro Level Practices to Adapt to Climate Change for African Small Scale Farmers*. International Food Policy Research Institute, 2010; Retrieved 4th February, 2012 from www.ifpri.org/publications
16. Conway, G.; *The Science of Climate Change in Africa: Impacts and Adaptation*, Grantham Institute for Climate Change, London, 2009
17. Kagwanja, J.; *The Impact of Climate Change on African Agriculture: Options for Building Resilience, A Symposium on Dialogue on Agriculture and Food Security Swiss Development Corporation, Berne Switzerland*; 2010
18. Chijioke, B.O., Haile, M. and Waschkeit, C. (2011), *Implication of Climate Change on Crop Yield and Food Accessibility in sub-Saharan Africa* Centre for Development Research, University of Born; 2010
19. African Ministerial Council on the Environment (AMCEN), *Addressing Climate Change Challenges in Africa; A Practical Guide towards Sustainable Development*; 2011
20. Yanda, P.Z. and Mubaya, C.P *Managing Climate in Africa: Local Level Vulnerabilities and Adaptation Experiences* MKUKI NA NYOTA, Dar es Salaam, Tanzania; 2011
21. Molua, E. (2002) “Climate Variability, Vulnerability and Effectiveness of Farm Level Adaptation Options: The challenges and Implication for Food Security in Southern Cameroon” *Journal of Environment and Development Economics* Cambridge University Press UK; 2002; 7: 529-545

22. United Nation Framework Convention on Climate Change **Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries 2007**, Retrieved 8th October, 2014 from www.unfccc.int
23. Mbilyinyi, A., Saibul, G.O. and Kazi, V., Impact of Climate Change to Small Scale Farmers Voices of Farmers in Village Communities in Tanzania ESRF Discussion, 2013, Paper No. 47. Retrieved 15th July, 2015 from www.esrftz.org
24. Thompson, H.E., Berrang-Ford, L., Ford, D.J., Climate Change and Food Security in Sub-Saharan Africa: A Systematic Literature review. *Sustainability*, 2010; 2, 2719-2733. Retrieved 11th February, 2016 from www.mdpi.com/journal/sustainability
25. Harvey, C.A., Rakotobe, Z.L, Rao, N.S, Dave R., Razafimahatratra, H. Rabarijohn, R.H., Rajaofara, H. and MacKinnon, J.L. Extreme Vulnerability of Smallholder Farmers to Agricultural Risks and Climate Change in Madagascar Phil. Trans. R. Soc. B369: 20130089. 2014, Retrieved 11th June, 2015 from <http://dx.doi.org/10.1098/rstb.2013.0089>
26. Wall, E., Smit, B., Wandel, J. (Eds) *Farming in Changing Climate: Agricultural Adaptation in Canada* University of British Columbia Vancouver Toronto, 2007
27. Fussel, H.M. "Adaptation Planning For Climate Change: Concept, Assessment Approaches and Key Lessons" *Journal of Sustainability science*, 2007; 2, 265-275
28. Wall, E. & Smit, B. Climate Change Adaptation in Light of Sustainable Agriculture *Journal of Sustainable Agriculture*, 2005; 27(1), 113-123
29. Rickards, L., Hayman, P., Eckard, R (2011) Agricultural Adaptation to Climate Change: Acknowledging Different Frames In Proceeding of the 5th World Congress of Conservation Agriculture, Incorporating 3rd Farming System Design Conference, Brisbane, Australia, 26-29 September, 2011
30. Kelly M. P & Adger N. W. Theory and Practices in Assessing Vulnerability to Climate Change and Facilitating Adaptation *Journal of Climate Change*, Kluwer Academic Publishers, Netherland, 2000; 47, 325-352
31. Kim, Chang-Gil., Lee, Sang-Min., Jeong., Hak-Kyun., Jang, Jeong-Kyung., Kim, Yoon-Hyung., Lee, Chung-Kuen., "Impacts of Climate Change on Korean Agriculture and Its Counterstrategies", Korea Rural Economic Institute, 2010
32. Adger W.N, Arnell, W. N, and Tompkins L.E., "Successful adaptation to climate change across scales" *Journal of Global Environmental Change*, 2005; 15,77-86. Retrieved on 15th June, 2012 from www.elsevier.com/locate/gloenvcha
33. Smit, B., Sknner, W. M. (2002) "Adaptation Options in Agriculture to Climate Change: A typology" *Journal of Mitigation and Adaptation Strategies for Global Change*, Kluwer Academic Publishers, 2002; 7:85-114
34. Smit, B, Burtonn, I, Klein, J.T.R and Street, R (1999), "The Science of Adaptation: A Framework for Assessment" *Journal of Mitigation and Adaptation Strategies for Global Change*, 1999; 4 (3), 199-213. Retrieved 21st December, 2010 from
35. Nakashima, D., and Rou'e, M. (2002) Indigenous Knowledge, Peoples and Sustainable Practice In Timmerman (Ed), *Social and Economic Dimension of Global Environmental Change, Encyclopedia of Global Environmental Change Chichester, Wiley and Sons*, 2002; 5, 314-324
36. Fankhauser, S. & McDermott, K. J. T. (2013) Understanding the Adaptation Deficit: Why are the Poor Countries more Vulnerable to Climate Events than Rich Countries Grantham research Institute on Climate Change and the Environment
37. Swiderska, K., and Reid, H., Song, Y., Li, J., Mutta, D., Ongugo, P., Pakia, M., Oros, R., and Barriga, S., The Role of Traditional Knowledge and Crop Varieties in Adaptation to Climate Change and Food Security in SW China, Bolivian Andes and coastal Kenya in *UNU-IAS Workshop on Indigenous Peoples, Marginalised Populations and Climate Change: Vulnerability, Adaptation and Traditional Knowledge, Mexico, July 2011*
38. Rickards, L. and Howden M. S. "Transformational Adaptation: Agriculture and Climate Change" *Journal of Crop and Pasture Science*, 2012; 63, 240-250. Retrieved 14th June, 2014 from <http://dx.doi.org/10.1071/CP11172>
39. Kronik, J. and Verner D., The Role of Indigenous Knowledge in Crafting Adaptation and Mitigation Strategies for Climate Change in Latin America in Mears and Norton (eds.) *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. Washington DC, World Bank, 2010, page 145-172
40. Howden S. M, Soussana J. F., Tubiello F. N., Chhetri N, Dunlop M, Meinke H Adapting agriculture to climate change *Proceedings of the National Academy of Sciences of the United States of America*, 2007; 104, 19691-19696. Retrieved 16th July, 2012 from doi:[10.1073/pnas.0701890104](https://doi.org/10.1073/pnas.0701890104)

41. Ouda, S; Zohry, A Climate-Smart Agriculture Reducing Food Insecurity 2022; Springer Nature Switzerland AG, <https://doi.org/10.1007/978-3-030-93111-7>
42. Tristi, D. A., (2021) *Adaptation Strategies of Smallholder Farmers using Climate-Smart Agriculture : the case of Rejosari Village, Indonesia; 2021*
43. Abegunde, O.V., Sibanda, M., Obi, A.; Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa, *Sustainability* 2020, 12, 195
44. Makate, C. Local institutions and indigenous knowledge in adoption and scaling of climate-smart agricultural innovations among sub-saharan smallholder farmers. *International Journal Climate Change Strategies and Management*; 2019; 12(2), 270–287.
45. Amimo, V.F. Investigations on climate smart agriculture practices use among smallholder farmers to cope with climate change and variability in Mozambique. [Unpublished Masters thesis]. University of Zimbabwe; 2019.
46. Haulle, E. (2007), *The Role of Traditional Environmental Knowledge Systems in Earthquake Disaster Management in Ludewa District, Tanzania*, Unpublished M.A. Dissertation University of Dar es Salaam
47. Institute of Resource Assessment (2007), *Environmental Impact Statement for the Proposed Development of Sponge Iron Industry and Steel Allied Products in Ludewa District, Iringa Region, Tanzania*, Report Submitted to National Environmental Council.
48. The Research Advisors (2006), *Required Sample size* Retrieved on 19th November, 2012 from <http://research-advisors.com>
49. Boyd, P., (2002). "Sampling Concepts" MBA Faculty Conference Papers & Journal Articles, Paper 2. Retrieved 19th November, 2012 from http://scholarsarchive.jwu.edu/mba_fac/2
50. Haule, B.M.C., (2009) *Assessment of Change in Smallholder Farmers' Livelihoods due to Land Degradation in Ludewa District, Tanzania*, Doctor of Philosophy Thesis, Sokoine University of Agriculture, Morogoro, Tanzania
51. Nyong A., Adesina, F. and Elasha, O. B. (2007), *The Value of Indigenous Knowledge in Climate Change Mitigation and Adaptation Strategies in the African Sahel*. Retrieved 10th June, 2010 from <http://ies.lbl.gov/iespubs/8nyong.pdf>
52. Kaur, G. (2013) Sustainable Development in Agriculture and Green Farming in India OIDA *International Journal of Sustainable Development* 06: 12. Retrieved 18th September, 2014 from <http://www.ssrn.com>
53. Anthony, D (2007), *Traditional Environmental Knowledge Systems Related to Changes and Variations of Water Resources Management in Semi-arid, Tanzania A Case of Mara River Basin*. Unpublished Ph.D Thesis, University of Dar es Salaam
54. United Republic of Tanzania (2013c), **Preparation of an Integrated Water Resources Management and Development Plan for Lake Nyasa Basin: Climate Change Report** Ministry of Water, Lake Nyasa Water Basin Board
55. United Republic of Tanzania (2011b) **Tanzania Bread-Basket Transformation Project: A Pilot Programmes for the Kilombero and Southern Highland Regions**, Ministry of Agriculture Food Security and Cooperatives
56. United Republic of Tanzania (2005b), **National Strategy for Growth and Reduction of Poverty (NSGRP)**. Vice President's Office Dar es Salaam.
57. United Republic of Tanzania (2010), **National Strategy for Growth and Reduction of Poverty (NSGRP)**. Vice President's Office Dar es Salaam.
58. United Republic of Tanzania (2013b), **National Agricultural Policy** Ministry of Agriculture Food Security and Cooperatives Dar es Salaam, October 2013
59. El-Samnoudi IM, Ibrahim AM, Abd El Tawwab AR, Abd E-MA Combined effect of poultry manure and soil mulching on soil properties, physiological responses, yields and water-use efficiencies of sorghum plants under water stress; *Commun Soil Sci Plant Anal*; 2019 50(20):2626–2639. <https://doi.org/10.1080/00103624.2019.167144>
60. Roncoli, C., Ingram, K. and Kirshen, P. (2002), Reading the Rains: Local Knowledge and Rainfall Forecasting In Burkina Faso. *Journal of Society and Natural Resources*, 15:409-427.