Chapter

Climate Change Implications to High and Low Potential Zones of Tanzania

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Abstract

This chapter presents the findings from a literature review distinguishing the levels of vulnerability and resilience between the people who live in high potential zone areas and low potential zone areas. High potential zones are natural-resourced areas, while low potential zones are less-resourced areas. The refereed resources include fertile soil, water sources, vegetation, and landscape just to mention a few. Predictions from global circulation models confirm that global warming will have substantial impacts to biodiversity and agricultural systems in the most developing countries, including Tanzania. These impacts are severe, significant, and more pronounced in low potential zones where the poor people always dwell. High potential zones are less vulnerable to these impacts due to resources endowments. These impacts are mainly exacerbated by anthropogenic activities like overgrazing, burning of the ecosystem, and monoculture to mention a few. The increase in stress to the already affected areas increases the vulnerability of the poor and thus squeezing the threshold of livelihood options. This chapter focuses on climate change and biodiversity (i.e., soil, landscape, and vegetation) and agricultural biodiversity for climate change adaptations. Therefore, coping and adaptation strategies, particularly economic and technological adaptations, are relented as they significantly reduce the vulnerability of the livelihoods.

Keywords: adaptation, agriculture, biodiversity, climate change, high and low potential zones, Tanzania, vulnerability

1. Introduction

This chapter aimed at viewing the differences in vulnerability levels between the people living in high potential zones and those living in low potential zones [1, 2]. The vulnerability refereed is that caused by stress and shocks caused by the impacts of climate change [3]. The global weather change has determined the livelihood setups in most developing countries [4]. In the countries with varied ecological gradients and agroecological zones, we expect diverse impacts in the livelihood systems [5]. Tanzania has seven agroecological zones with different soils, rainfalls, temperatures, vegetations, locations, and altitudes just to mention a few [6]. Some of these zones are endowed with diverse natural resources (high potential zones) like fertile soil, water sources, and favorable climate to mention a few, while other zones are poorly endowed (low potential zones). Therefore, the people in diverse zones have different entitlements. Their responses to stress are varied depending on the livelihood assets and vulnerability [7]. In this aspect, vulnerability may refer to lack of asset to absorb shocks and recover from stress. Some of these assets include human, capital, physical, and technology just to mention few. Over the past two decades, most marginal areas (low potential areas) have been experiencing regular food insecurity due to poor crop yields [8]. This situation has been exacerbated by the rainfall variability, that is, change in seasons, erratic rainfalls, and increased droughts, which affects agricultural systems and reduces crop yields. According to Afifi et al. [9], climate change contributes up to 80% of crop failure in most vulnerable agricultural systems in Tanzania.

Since the 1990s, a number of wealth research findings have been done in Tanzania to address climate change impacts and its vulnerability. Among these studies are the following: Ahmed et al. [1], Paavola [3], Rowhani et al. [4], Yanda [5], Agrawala et al. [2], Mkonda and He [8], and Afifi et al. [9]. Despite addressing the temporal and spatial variability of climate change, most of these studies have limited focus on the ground exploration between the people living in low potential zones and those in high potential zones. The studies generally execute on how these impacts affect livelihoods but with little magnitudes on the comparison between groups. Climate change is expected to affect African countries in a variety of ways. For example, temperatures in Tanzania and the whole East African region are expected to rise by between 2 and 4°C by 2100, thus shifting agroecological zones in most areas [5, 10]. However, the impacts will be more pronounced in the already affected areas, especially in the semiarid agroecological zones and other marginal areas.

Predictions from global circulation models confirm that global warming will have a substantial impact on biodiversity and agricultural systems in Tanzania [11]. The changing weather patterns such as less predictable seasons, increasing events of erratic rainfall, and prolonged drought will stress on the already stressed areas and will threaten the sustainability of agriculture and food security in most parts of Tanzania [12]. Tanzanian rainfall is predicted to increase in areas with bimodal rainfall pattern from 5 to 45%, while decreasing in those with unimodal rainfall patterns from 5 to 15% [4, 13].

The vulnerability is going to increase in areas experiencing decreased rainfall, thus affecting livelihood systems of the dwellers [14, 15]. Soil replenishment through organic matter decomposition cannot simply take place in these areas [16]. Some areas with increasing rainfall may experience temporary floods and loss of soil fertility through leaching and runoff [5]. Under normal conditions, most of the poor people are squeezed in low potential zones due to entitlement failure [17]. As a livelihood strategy, some of these people living in marginal areas migrate to other areas.

They migrate (some with their herds of cattle) to areas with suitable agricultural systems and economic diversification [6, 18–20]. A good example is Usangu valleys (alluvial plain agroecological zone) which act as a destination of different people, especially pastoralists from other region with stressed environments.

Although the impacts of climate change have been globally established, there is a need to assess the magnitude of these effects in local conditions and diverse ecological gradients. Therefore, this chapter establishes the differential resiliences to climate impacts based on high and low potential zones. This will even enable climate practitioners and policy analysts to estimate the level of adjustments needed to curb climate impacts [21].

2. Location

Tanzania is located on the eastern coast of Africa, south of the equator, between latitudes 1° 00′ S and 11° 48′ S and longitudes 29° 30′ E and 39°45′. The eastern side of Tanzania is a coastline of about 800 km long marking the western side of

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Zone	Sub-zones	Soil and topography	Altitude	Rainfall (mm/yr)	G/season
1. Coast	North: Tanga (except Lushoto), Coast, and Dares Salaam	Infertile sands on gently rolling uplands Alluvial soils in Rufuji sand and infertile soils	Under 3000 m	North: bimodal, 750–1200 mm	North: October–December and March–June
	South: eastern Lindi and Mtwara (except Makonde plateau)	Fertile clays on uplands and river flood plains		South: unimodal, 800–1200 mm	South: December–April
2. Arid lands	North: Serengeti, Ngorogoro Parks, and part of Masailand	North: volcanic ash and sediments. Soils are variable in texture and very susceptible to water erosion	North: 1300–1800 m	North: unimodal, unreliable, 500–600 mm	March–May
	Masai Steppe, Tarangire Park, Mkomazi Reserve, Pangani, and Eastern Dodoma	South: rolling plains of low fertility susceptible to water erosion Pangani river flood plain with saline and alkaline soil	South: 500–1500 m	South: unimodal and unreliable, 400–600 mm	
3. Semiarid lands	Central Dodoma, Singida, Northern Iringa, some of Arusha, and Shinyanga	Central: undulating plains with rocky hills and low scarps. Well-drained soils with low fertility. Alluvial hardpan and saline soils in eastern rift valley and Lake Eyasi Black cracking soils in Shinyanga	Central: 1000–1500 m	Central: unimodal and unreliable: 500–800 mm	December–March
	Southern: Morogoro (except Kiliombero and Wami Basins and Uluguru Mts.) and also Lindi and Southwest Mtwara	Southern: flat or undulating plains with rocky hills, moderate fertile loams and clays in South (Morogoro), and infertile sand soils in center	Southeastern: 200–600 m	Southeastern: unimodal: 600–800 mm	
4. Plateaux	Western: Tabora, Rukwa (north and center), and Mbeya	Western: wide sandy plains and rift valley scarps	800–1500 m	Western: unimodal, 800–1000 mm	November–April
	North: Kigoma, part of Mara	Flooded swamps of Malagarasi and Ugalla rivers have clay soil with high fertility			
	Southern: Ruvuma and Southern Morogoro	Southern: upland plains with rock hills Clay soils of low to moderate fertility in south, and infertile sands in north		Southern: unimodal, very reliable, 900–1300 mm	

Zone	Sub-zones	Soil and topography	Altitude	Rainfall (mm/yr)	G/season
5. Southern and western highlands	Southern: a broad ridge from N. Morogoro to N. Lake Nyasa, covering part of Iringa, Mbeya	Southern: undulating plains to dissected hills and mountains. Moderately fertile clay soils with volcanic soils in Mbeya	Southern: 1200–1500 m	Southern: unimodal, reliable, and local rain shadows, 800–1400 mm	Northern: December–April
	Southwestern: Ufipa plateau in Sumbawanga	Southwestern: undulating plateau above rift valleys and sand soils of low fertility	Southwestern: 1400–2300 m	Southern: unimodal, reliable, and 800–1000 mm	Southwestern: November–April
	Western: along the shore of Lake Tanganyika in Kigoma and Kagera	Western: North-south ridges separated by swampy valleys, loam and clay soils of low fertility in hills, with alluvium and ponded clays in the valleys	Western: 100–1800 m	Western: bimodal, 1000–2000 mm	Western: October–December and February–May
6. Nothern highlands	Northern: Foot of Mt. Kilimanjaro and Mt. Meru Eastern rift valley to Eyasi	Northern: volcanic uplands, volcanic soils from lavas and ash. Deep fertile loams. Soils in dry areas prone to water erosion	Northern: 1000–2500 m	Northern: bimodal, varies widely between 1000 and 2000 mm	Northern: November–January and March–June
	Granite Mts. Uluguru in Morogoro, Pare Mts. in Kilimanjaro and Usambara Mts. in Tanga, Tarime highlands in Mara	Granite steep mountain side to highland plateaux. Soils are deep, arable, and moderately fertile on upper slopes, shallow and stony on steep slopes	Granitic Mts.: 1000–2000 m	Granitic Mts.: bimodal and very reliable 1000–2000 m	Granitic Mts.: October–December and March–June
7. Alluvial plains	K—Kilomberao (Morogoro)	K—cental clay plain with alluvial fans east and west		K—Unimodal, very reliable, 900–1300 mm	K—November–April
	R—Rufuji (Coast)	R-wide mangrove swamp delta, alluvial soils, sandy upstream, loamy down steam in floodplain		R—Unimodal, often inadequate 800–1200 mm	R—December–April
	U—Usangu (Mbeya)	U—seasonally flooded clay soils in north, alluvial fans in south		U—Unimodal, 500–800 mm	U—December–March
	W—Wami (Morogoro)	W—moderately alkaline black soils in east, alluvial fans with well-drained black loam in west		W—Unimodal, 600–1800 mm	W—December–March

Source: URT [7].

Table 1.
Agroecological zones of Tanzania.

the Indian Ocean. Tanzania has a total of 945,087 km^2, and out of this area, water bodies cover 61,495 km^2 which is equivalent to 6.52% of the total area.

The country has about 44 million hectares of arable land. Tanzania has seven agroecological zones (**Table 1**). Eastern plateau and mountain blocks; southern highlands; northern highlands/northern rift valley and volcanic high lands, arid lands/central plateau; alluvial Plains/Rukwa-Ruaha rift zone; and semiarid lands/ inland sedimentary plateau.

Therefore, this study aimed to distinguish the level of vulnerability and proper adaptation strategies between the high and low potential areas of Tanzania [14].

3. Climate change and biodiversity

It is obvious that the impact of climate change will continue to affect the biodiversity in most developing countries [22]. These effects are more pronounced and significant in vulnerable agro-biodiversity. IPCC 2014 reports that Tanzania is among the 13 countries in the world which are affected and most vulnerable to the impact of climate change [23]. This is evidenced by the reality seen on the ground. In this sense, climate change has impacted crop production, forest ecology, fishery industry, and livestock just to mention a few [4, 20–22].

Furthermore, climate change has affected crop genetics, the functioning of the soil microbial (due to drought), landscape, and the entire livelihood systems of 75% of the Tanzanian population (i.e., farmers). Basing on our discussion, the people and biodiversity found in low/marginal areas are more stressed than those in high potential zones. The livelihood options of the poor people in the marginal areas are too limited as they entirely depend on the environment [5].

Currently, the environment is stressed and has failed to support the people, thus the people are further subjected into distress. Prospectively, climate change will affect the ecosystem services and agricultural biodiversity, and the magnitude of the impacts will differ according to biophysical characteristics of the particular area [13].

3.1 Climate change impact on crop production

The increase in temperature and decrease in rainfall (including the shift of rainfall pattern) have significant impact to crop production in most developing countries [1–5]. In most areas of the country, there is significant correlation between the trend of crop production and that of rainfall [3–5]. In the years with poor yields, there have been incidences of low rainfall.

Agricultural systems are affected by drought and erratic rainfall, and therefore, the condition cannot support crop production. Specifically, crop failure has been more pronounced in the semiarid (i.e., Dodoma, Singida, Tabora, Manyara, and Shinyanga regions) due to prolonged drought and poor soil replenishment [2, 13]. Therefore, semiarid is among the marginal areas with excessive drought, crop failure, and food insecurity [3, 24]. As adaptation measure, farmers are advised to use drought-resistant crops and diverse crop varieties which are tolerant to drought [7, 14].

For example, SARO 5 rice varieties have been adopted in some rice-producing areas (such as Kilombero and parts of Kilosa districts) that face frequent droughts. Agronomic practices done in most marginal areas provide insights on how to optimize climate resilience in these areas. The dominant agricultural systems in these areas are monoculture, shifting cultivation, and extensive livestock rearing just to mention a few [21]. These practices have significant impacts to soil and its ingredients [21, 22, 24, 25].

However, there are limited soil management practices that are sustainably done in these areas [3]. Comparatively, the high potential zones experience little impacts than their counterparts. According to IPCC 2014, Tanzania will experience diverse impacts of climate change in the agriculture sector [23]. It is predicted that rainfall will increase in bimodal rainfall pattern (high potential zone) and decrease in unimodal rainfall pattern (low potential zone), therefore affecting the already stressed areas (low potential zone). In the high potential zone, especially in Eastern Arc Mountain and alluvial plain just to mention few, the natural replenishment of soil fertility through litter and/or organic matter decomposition is high because the microbial processes such as mycorrhizae can adequately perform their functions [26, 27]. Subsequently, carbon sequestration seems to be more significant in these areas [28, 29]. Therefore, these areas become potential for crop production and other livelihood patterns as they support diverse production systems.

3.2 Climate change impact on the soil

Climate is among the significant factors in the formation of the soil. Specifically, temperature, rainfall, and atmospheric carbon have specific function in the decomposition of litter and other plant biomass to organic matter [30]. The concentration of atmospheric CO_2 increases the growth rate and water-use efficiency of crops and natural vegetation [5]. Subsequently, the increased microbial activity in the soil always leads to the increase in the rates of plant nutrient release (e.g., C, K, Mg, and trace nutrients just to mention a few) from weathering of soil minerals. Similarly, the mycorrhizal activity leads to better phosphate uptake [31].

Subsequently, the increase in soil temperature creates a favorable condition for microbial activity. In turn, this increases the rate of organic matter and litter decomposition for forming soil fertility. Among the soil nutrients formed in this process are soil organic carbon, total nitrogen, and soil Olsen-P [27, 30, 31]. These nutrients are significant for plant uptake for growth and increased production. These processes are more pronounced in the high potential zone than in the low potential zone [5–7].

Therefore, high potential zones can produce more crop yields than low potential zones and therefore, the peoples' livelihoods in these areas are potentially better [3–8]. For instance, in the northern highland of Tanzania, granite soil is dominant, and this soil is useful for plant growth and improvement of agricultural systems in those areas. Therefore, these two zones have distinct characteristics and they offer diverse livelihood options [15].

3.3 Effects of rainfall on the landscape

The increase and decrease in rainfall have diverse impacts to different landscapes. This brings insight that different landscapes may have different ways to adapt to climate change impacts [7–9]. Geographically, highland areas have different biophysical characteristics from lowland areas. It is noted that landscape determines the flow of water runoff and infiltration [6]. It is expected that in plain areas with well-drained soil, there will be loss of soil nutrient through infiltration, while in steep slope with compact soil, nutrient will get lost through water runoff [5–10].

This scenario is expected to be significant in bimodal rainfall where rainfall is expected to increase [6]. In Mvomero and Kilosa districts of Morogoro region, there have been frequent occurrences of floods due to heavy rains [5]. This hazard is propagated by the characteristics of the landscape, that is, highland and lowland. Similarly, landslides and mudflow have been occurring and are significantly expected to occur in these areas [5].

Besides, drought is expected to be pronounced in areas with unimodal rainfall pattern [6]. And this will pose effects depending on the landscape of the area. In this aspect, steep slope will experience poor soil formation and thus the area is not favorable for agriculture. Lowland areas may experience less impacts of drought than highland areas [5]. And this brings insights that agricultural potentials may differ between the two areas.

Basing on the potentiality of the area (high and low potential zones), lowland areas often receive nutrients and water from highland areas through runoff and therefore improve the agricultural systems of the locality [1–3]. Highland and steep slope areas might be vulnerable to environmental stress, thus providing less potentials in agricultural systems unless there are other sources of resources, that is, water and soil fertility [6–10]. To control this, some farmers and institutions have been practicing some farming systems that are ecologically significant to adapt to climate change and impacts related to environmental stresses [1–6]. Preferably, conservation agriculture has been opted as a possible absorber of these stresses and shocks. The "Matengo" farming systems in Ruvuma region and the "Ngitiri" pasture farming in Shinyanga, just to mention a few, are some good examples of the mentioned conservation agriculture [5–9].

3.4 Climate change impact on agricultural systems

The increase in temperature at both global and local levels is predicted to impact a wide range of biodiversity, including the extinction of some animals and plant species [7]. The predicted increase in temperature by 1.5–2.5°C will increase the concentration of atmospheric carbon dioxide and eventually affect the ecosystem functions, biotic species, ecological interactions, and water supply. IPCC 2014 predicts that by 2100, the threshold of resilience of most ecosystems is going to be reduced and narrowed naturally [23].

Agricultural systems (animal and crop production) are most concerned in this case. Temperature will increase incidences of drought, flooding, wildfire, ocean acidification, eutrophication (especially in Lake Victoria), and pollution just to mention a few. As a response to this, farmers engage in land-use changes and overexploitation of resources to meet their needs [6].

Besides, ecosystem services, particularly sources, will be severely affected. However, the magnitude of these impacts will differ depending on the level of vulnerability, that is, high and low potential zones [10]. There will be relief to some agroecological zones (with high potentials) and severe impacts to low potential zones [12–16]. This will also be based on the ecological gradient and landscape of the area. Losses of biodiversity (agroecological systems) will automatically affect food security and socioeconomic challenges caused by ecological challenges.

Livestock rearing, on the other hand, will experience similar impacts. Some genetic breeds which are vulnerable to climate change impacts will be substituted by drought-resistant breeds. In most drought areas of Tanzania, drought-resistant animals have been replacing the vulnerable ones. Camels (i.e., though few) have been adopted instead of goat, sheep, and cow just to mention a few.

Basing on the actual and potential impacts of climate change on resources, some adaptation strategies and mechanisms have been adopted to reduce the magnitude of the impacts [3]. Similarly, landscapes have been determining the best use of the land [3–8]. Previously, highland areas (southern highland of Tanzania) have been used for tea and coffee plantations. However, due to the changing climate, these areas have become warmer than before and therefore are not conducive for these crops.

Instead, maize, beans, and other moderate crops have been grown in these areas as paradigm shift [3–6]. And thus, coffee, tea, and pyrethrum have been grown in small scale or are totally redundant due to change of weather.

4. Agricultural biodiversity for climate change adaptation

Adaptive capacity to climate change impacts is varied over space and time. People have diverse capacity to adapt to climate change impacts [15–20]. Some are vulnerable, while others are resilient and they can recover soon from the impacts. Similarly, the thresholds of adaptive capacity is subject among other things to resource entitlements, that is, human asset, financial asset, physical asset, and technological asset just to mention a few [21, 22, 24].

Tanzania has identified a wide range of adaptation strategies through National Adaptation Program for Action [6]. The identified adaptations were based on location (ecological gradients), resource endowments, livelihood options, financial assets, and agroecological zone just to mention a few.

Altitude and climate were among the other significant factors in this chapter. The main aim of the program was to identify and recommend proper adaptation strategies that would reduce the vulnerability and increase the resilience of the farmers. Meanwhile, the program comes up with the wide range of adaptation option based on the aforementioned factors [24–26].

The recommended adaptation strategies include the growing of drought-resistant crops such as cassava (*Manihot esculenta* C.), sesame (*Sesamum indicum* L.), sweet potatoes (*Ipomea Batatas* L.), and pigeon peas (*Cajanus cajan* L.). Further, crop diversification was another adaptation strategy. This involved the growth of different types of crops (both food and cash crops) in order to avoid total loss.

Modern farming techniques, changing cropping calendar, and involvement of nonfarming activities were other adaptation strategies. All these are done to curb food security in the country [5–8]. Subsequently, the program report shows that there is spatial and temporal variation of onset and cessation of rain and dry seasons [15–18]. The trend of rainfall and dry season during 1980–2010 shows that it is not statistically significant different ($P > 0.05$). Thus, erratic rainfall and rain patterns are significant in determining climate impacts.

Similarly, agricultural and research institutes are responsible to review on the current changes and current recommended adaptation strategies. Policies, plans, frameworks, and projects related to agriculture and environment are keen to accommodate adaptation strategies in their action and implementation for sustainable development of both agriculture and environment. Likewise, enhancing ecosystem services (management and payment of ecosystem services) is a suitable approach of strengthening the adaptation strategies [5–8].

Both abiotic and biotic factors need to be well accommodated in the planning in order to reduce the magnitudes of climate change impacts [26–29]. Abiotic factors may range from heat, salinity, floods, and drought to mention a few, while biotic factors are all aspects of living organisms found in the environment [6–8]. For more explanation, see the subsections below which describe specific adaptation approaches.

4.1 Animal genetic resource

About 30% of the Tanzanian land is under arid and semiarid climates, of which its main activities are extensive livestock keeping and some mixed farming [6, 13]. Therefore, livestock is among the major livelihoods and is a tool of increasing resilience from the stress caused by climate change [21]. However, the impacts of climate change have subjected livestock into stress and will continue affecting it. This is more pronounced in most central regions of Tanzania.

This situation dries water sources and affects grasses in the pasture and range land required for animal grazing [26–29]. In turn, the situation affects most animals, and most of them die due to shortage of pasture and water. From 2008 to date, thousands of animals have died in Manyara (i.e., Kiteto District), Arusha, Shinyanga, Dodoma, and Singida regions due to drought [13–18]. In this stance, evidences show that cows have been more vulnerable than goats and sheep. Similarly, the increase in temperature stresses the already affected areas and catalyzes the outbreak of disease and pests which affect the animals [5–10]. As a result, a number of animals have been dying due to diseases and pest [6–8]. The effects have been more severe to some types of animal breeds/or and species due to differences of the level of tolerance.

Some measures have been taken by the government and local people to adjust to stress. The government has been advocating intensive livestock keeping for the purpose of increasing quality and quantity of the product and reducing overgrazing on the already stressed areas [6, 13]. Pastoralists have been shifting from the stressed environment (low potential zone) to areas with pasture and water (high potential zone). The Usangu valley in Mbeya region (high potential zone) has been the actual and potential destination of most pastoral societies [6–10].

These pastoralists are after water and pasture for feeding their herds. Therefore, planners and policy makers need to integrate this challenge in order to rescue environmental degradation by pastoral societies as well as to reduce the disturbances to pastoralists.

4.2 Crop genetic resources

It is obvious that crop production can be the most affected sector by stresses and shocks of climate change [5–8]. Increased incidences of drought have reduced crop yield massively. A number of studies show that crop production has been significantly affected by climate change impacts [3–5]. Crop species that need more moisture are more vulnerable than those which need little. Hybrid maize is among those which are less resistant to drought due to that factor.

Therefore, a number of crop species have been lost because they can no longer tolerate to the present climate change impacts. As adaptation strategies, resistant crops such as SARO 5 rice species have been adopted to reduce the vulnerability of rice crop [7–10]. Otherwise, irrigation agriculture has been recommended as a solution to accommodate a wide threshold of crop species.

In Kilombero, Mtibwa, Usangu, and Ruvu Basin, rice production has been growing due to irrigation. However, only 2% of the Tanzanian land potential for irrigation agriculture has been harnessed. Therefore, the vulnerability of crop species varies depending on where it is grown. In high potential zones, the crop breed may have a wide chance to survive than in low potential zones [15].

4.3 Adaptation in agricultural systems

Agriculture provides full livelihoods to more than 75% of the Tanzanians and most of them are living in rural areas [5–8]. Therefore, it is very important to make sure that adaptation strategies and coping mechanisms to the impacts of climate change are taken into full consideration [1–4]. Different agroecological zones may have diverse adaptation measures depending on the climate, soil, financial asset, and human asset just to mention a few. It is obvious that low potential areas are the most fragile ecosystems and when mismanaged even the little potentials may get lost [5–8].

Therefore, a wide range of adaptation measures are considered in various areas of the country [5–10]. Some of the general adaptation measures taken across the country includes shifting cultivation (to more potential areas), adopting drought-resistant crops like cassava (*Manihot esculenta* C.), sesame (*Sesamum indicum* L.), and sweet potatoes (*Ipomea Batatas* L.), rice (*Oryza sativa L.*), banana (*Musa* Spp.), and maize (*Zea mays* L.) should be incorporated in irrigation agriculture to reduce their vulnerability and increase yields [31–33].

Another adaptation related to agricultural system is the change of agronomic practices [5–12]. In this aspect, the adaptation of conservation agricultural practices such as agroforestry, better crop rotation, mixed farming, and intercropping [15–20] will help to improve organic soil fertility, preferably soil carbon. This will increase crop yields and carbon sequestration of greenhouse gases. This goes together with the adoption of modern farming techniques, particularly irrigation [21, 22, 24–26]. Tanzania has done very little in irrigation agriculture because it has harnessed only 2% of the total irrigable land.

Therefore, there is a need to work on it and increase the land under irrigation in order to curb all aspects of food insecurity in the country and increase the export of agricultural products. Similarly, early planting is adopted to curb the variation of onset and cessation of both rainy and dry seasons [26–29]. Erratic rainfall and the shift of onset has been a key problem in most areas in the country [15–18]. Despite the prediction that rainfall will increase in areas with bimodal rainfall pattern, these areas suffer the same problem of paradigm shift of the growing season.

In has been noted that most of the bimodal rainfall pattern have been experiencing unimodal rainfall with a great shift [4–8]. Meanwhile, experience from the field shows that the amount of rainfall has been changing in a roughly regular pattern. There have been roughly rotating patterns, that a year with low rainfall is followed by the year with high rainfall and vice versa [15–20]. Therefore, further adaptation strategies are needed to be accommodated as climate continues to change. We need to incorporate strong adaptation measures in the policy in order to curb food insecurity in the country.

Nonfarming practices can also help to strengthen the resilience of the people [26–29]. Diversified sectors such as commercial enterprises and employment just to mention a few, can help to reduce the dependence on the already stressed agroecosystems [30–33]. Therefore, diversification will enable the replenishment of the soil resources tenable for crop production.

4.4 Changes in agricultural practice

Traditional agriculture has been in practice even before the Tanzanian independence [5–8]. Indigenous knowledge has been limited to solve complex challenges posed by climate change. It is obvious that the number of people has been increasing every year and the demand of food has been accruing too [8–11]. Sustainable agriculture is currently advocated in order to get duo benefits (environmental conservation and increased crop yields) at the same time [1–6]. It is a great challenge for the country with about 44 million hectares of fertile land; less than 24% of this resource is harnessed while the country experiences usual food shortage [6–8].

The adoption of modern farming methods especially irrigation agriculture can increase crop yield to curb food insecurity. Agroforestry system is less adopted in the country, compared to its needs. The Eastern Arc Mountain in Tanzania has the potential for agroforestry but it is least harnessed [27].

In addition, Tanzania has a number of hydroecological zones such as the Ruaha, Rufiji, Ruvu, Wami, Ruvuma, Usangu, Pangani, Kilombero, and Malagarasi valleys just to mention a few [6–10]. These areas have potential for irrigation agriculture, but the actual situation reveals that there is underutilization and mismanagement of these resources [6]. Instead, these valleys have been sources of conflicts between resource users, therefore posing no or little benefit to users [3–8].

Therefore, good agricultural practices need to be adopted to increase crop yields in various areas. It has been obvious that traditional, rain-fed agriculture is a major production technique to the people [27–30]. Rain-fed agriculture has been vulnerable to the impact of climate change since the 1980s to date [31–33]. The adoption of sustainable agriculture countrywide can help to reduce the vulnerability and calibrate a quick recovery of the affected areas.

5. Conclusion

Tanzanian agroecological zones (i.e., high and low potential zones) experience the impacts of climate change differently. Semiarid areas experience the impacts of climate change more severely than the alluvial plains. This happens because the former is a low potential zone while the latter is a high potential zone. The vulnerability of the people also depends on the resource entitlements and assets they possess. Overall, poor people have little options than the rich people.

The two categories are differentiated by financial assets. It has been obvious that the poor always live in the low potential zone where they get more challenges and therefore they need a quick rescue; otherwise, their livelihood options are limited. Similarly, they can seek livelihood options by inserting more stress to the already affected environments. They move from the stressed areas to other areas where they end up degrading too.

This study recommends that farmers with weak adaptive capacity should be carefully and immediately attended to; otherwise, their livelihood options can further destroy the environment. The increase in awareness to local farmers in searching for sustainable livelihood options would be more secure to the environment. Similarly, relevant policies should clearly include practical adaptations of the vulnerable societies.

Conflict of interest

The author declares no conflict of interest.

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