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Vulnerability Assessment of the Livelihoods in Tanzania's Semi-Arid Agro-Ecological Zone under Climate Change Scenarios

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Abstract: Despite the established literature on the vulnerability to climate change in various parts of Tanzania, it is worthwhile to assess the extent of this vulnerability of the peoples' livelihoods and predict its future outcome. This is particularly important in the vulnerable ecosystems, that is, the semi-arid zones of Tanzania where the people's livelihoods are highly attached to the declining local condition. The present study aims to assess the livelihoods vulnerability in Kongwa District, the semi-arid zone of Central Tanzania. In doing so, a wide range of methods were employed during data collection and analyses including surveys, informative interviews, discussions and observation. The study sampled 400 ($\leq$10%) respondents during a survey. The Mann-Kendall Test with SPSS V20, Microsoft Excel and Theme content techniques were used for data analyses. The results indicate that climate stress has adversely impacted the quality of soil, vegetation, crop yields and intensified environmental degradation. Since most people depend upon the mentioned affected aspects, it is expected that also the level of livelihood vulnerability has elevated. Further, this situation has greatly contributed to increased poverty and thus, propagates the "tragedy of the common" to the available environmental resources. As a response to increased vulnerability, some farmers have abandoned thousands of hectares of agricultural farms that seemed to be less productive. Despite this, slight measures have been taken by both the government and other key stakeholders to limit vulnerability. The findings of this study provide a theoretical and practical basis for coordinating a sustainable man-environment relationship, ensuring the sustainability of the environment which is the major source of peoples' livelihoods.

Keywords: agricultural production; climate change; environmental sustainability; environmental tragedy; people's livelihoods; semi-arid ecosystems; vulnerability; Tanzania

1. Introduction

Prolonged degradation of environmental resources has recently become more rampant especially in the already stressed environment [1]. This has been continuously happening on a temporal basis and if strong measures are not taken, the situation can be deteriorated beyond restoration [2]. The degradation of environmental resources can severely affect the sustainability of the people's livelihood and the environment itself. This is because the devastated environment cannot provide services or support livelihoods. When explaining these aspects (i.e., environment, livelihoods and vulnerability) how do you link them? In this context, it is worth defining the term vulnerability. It is

obvious that numerous papers have been published in this respect, however, there is a need to make a temporal assessment of the livelihood vulnerability based on local conditions, that is, agro-ecological zones. This is because the level of vulnerability varies over space and time.

Figure 1 below outlines some empirical sources of vulnerability in most communities.

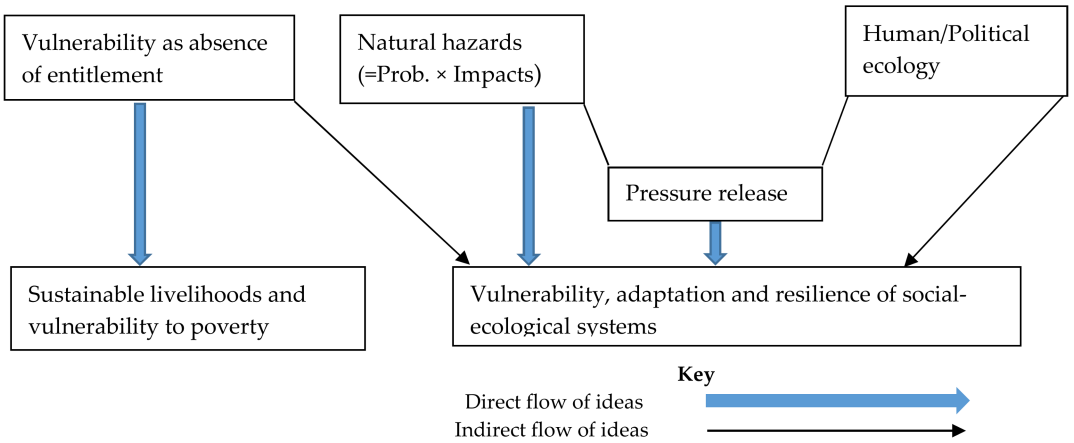

Figure 1. Sources of vulnerability and way to resilience. Source: Adapted from Adger [1].

According to Adger [1], vulnerability is typically described to be a function of three overlapping characteristics—namely exposure, sensitivity and adaptive capacity. It is further described as a state and as a set of factors that constitute that state and categorize certain individuals and groups as "vulnerable." In this aspect, a wide range of factors emanating from natural hazards, entitlement failure, social, political, economic, culture and ecology can significantly expose an individual or group of people into the state of vulnerability. Literally, most ideas on how to reduce the vulnerability can emanate from the lesson learned from the posed impacts. These ideas can be either direct or indirect (Figure 1) or in this; exposure, sensitivity and adaptive capacity are key aspects.

On the same basis, the Intergovernmental Panel on Climate Change (IPCC) [2] ranked Tanzania among the thirteen countries that are most vulnerable and have weak adaptive capacity to climate change impacts. In Tanzania, more than 70% of the population entirely depend on rain-fed agriculture and thus, any alteration in rainfall patterns has a direct impact on their livelihoods [3]. This assertion is supported by Ahmed [4], who affirmed that climate volatility made a significant contribution to poverty in Tanzania. In most incidences, poor people may exacerbate environmental degradation while trying to obtain their livelihoods on the already degraded areas. This perception is supported by Hardin [5] in his article on the "tragedy of the common," as he propounded that the poor are the worst degraders of the environment because, for them, the environment is the sole option on which they can sustain their livelihoods. In addition, the Millennium Ecosystem Assessment reports that the environment should be well conserved for the betterment of the people.

Some scholars, such as Paavola [6] and Challinor et al. [7], assessed the vulnerability of livelihood systems in Tanzania due to climate change and recommended some adaptation measures, however, the vulnerability of both livelihoods and the environment has remained high. The recent study by Rowhani et al. [8] and Mkonda [9] observed that climate impacts are still hitting crop production, livestock and other livelihood systems attached to the environment.

Despite the existence of some scientific studies, such as those of Challinor et al. [10] and Lobell et al. [11], which analyze the impacts of climate change on the environment, the present study assesses the impact of climate change on the environment and thereafter foresees the future outcomes.

This will help to determine the required pace of environmental restoration so that the extent of environmental degradation does not become so severe that restoration is not possible using currently available technology. This will also enable the planners, policy makers and related government

institutions to speed up the implementation of various environmental projects. Therefore, the major objective of this study was to identify more precisely the following questions: (i) Does climate change exist and affect the biophysical resources and, if so, how?; (ii) To what extent does climate change impact livelihoods; (iii) Do local people notice the environmental impacts caused by environmental change; (iv) Are there any sustainable measures that have been taken to improve the stressed environment?; and (v) Given to this vulnerability, what are the future prospects?

2. Materials and Methods

2.1. Profile of the Study Site

The Kongwa District is located between latitude 5°30′ to 6°0′ S and longitude 36°15′ to 36° E with an area of about 4041 km^2. The elevation of the district ranges from 900 to 1000 m above sea level. The district is on the leeward side of the Ukaguru Mountains. Mnyakongo and Ugogoni villages (Figure 2) were sampled for this study.

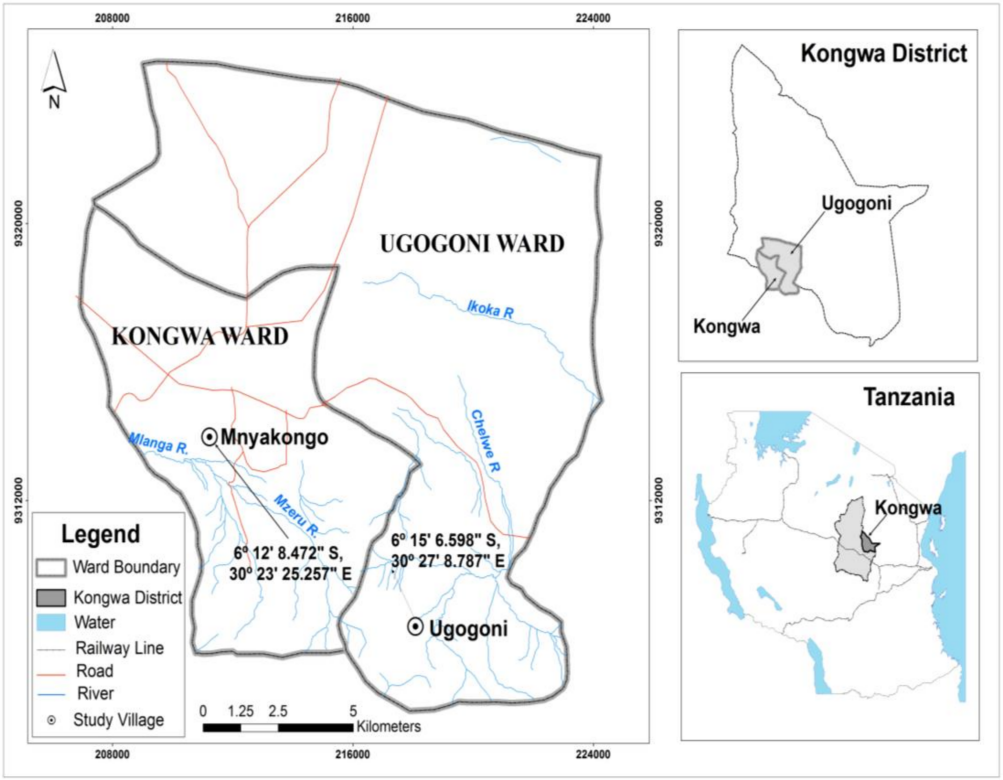

Figure 2. The Study Area. Source: IRA (Institute of Resources Assessment) GIS Lab, UDSM (University of Dar es Salaam): 2016.

According to a recent survey (2015), the current population of Kongwa District is estimated to be 318,995. This population grows at a growth rate of 2.4% per annum. The number of households is 60,301 with an average size of 4.9 persons. The number of farming households is 45,271, which is almost equal to 90% of the total households.

In terms of climate, the district is a semiarid area with a total annual rainfall ranging from 400 to 600 mm in the northern part and 600 to 800 mm in the southern. Besides, the mean annual temperature varies from 18 °C (minimum) to 34 °C (maximum). With little rain, that is, about 500 mm per year, the district has further been subjected to frequent droughts due to erratic and unreliable rainfall, prolonged dry spells and increasing incidences of peak temperature [8]. Eventually, this has caused

poor yields and frequent food shortages in the area [1–6]. Thereby, food shortage has been a dominant problem regardless of the geographical gradients, altitude, lithology and soils (Table 1).

Table 1. Main Physiographic Units and Soils in Kongwa District.

Physiographic Units	km^2	Altitude	Lithology	Dominant Major Soils
Mountains	400	980–2000	mainly Precambrian gneiss	Luvisols, Phaeozems, Leptosols, Ferralsols
Uplands	641	920–980	Acid and intermediate Metamorphic rocks	Luvisols, Ferralsols, Cambisols, Arenosols
Lowlands	3000	900–920	Unconsolidated materials	Fluvisols, Vertisols, Gleysols, Solonchaks

Source: Adapted from FAO-UNESCO [12].

2.2. Data Collection

This study was conducted between June and September 2016, in the Kongwa District, Dodoma Region, located in the semiarid zone of Tanzania. Different research methods such as questionnaires, informative interviews, physical observations and group discussions were employed for data collection (i.e., both quantitative and qualitative data). For more clarification, the questionnaire contains a set of questions that aims at acquiring data from the specific/targeted respondents. A household was the sampling unit for this study (Table 2).

Table 2. Respondents Profile in the Sampled Villages.

Region	District	Village	Total households	Respondents
Dodoma	Kongwa	Mnyakongo	2050	200
		Ugogoni	2080	200

Source: Field Survey Data, 2016.

Climate data were collected from weather stations in the villages and from the Tanzania Meteorological Agency for the years ranging from 1980 to 2015. The study designated such a time frame (35 years) because this gives ample time to determine the long-term rainfall variation. Thus, such a period (i.e., above 30 years) can determine the actual rainfall trend in a particular area. The temporal changes in the data were addressed in a number of ways. Firstly, the total annual rainfall was used to present the temporal data. Thereby, all changes or variations that happened during the time affected the total value of the particular year. Secondly, through open questions, the farmers were asked to mention the peak rainfall changes that happened over the years. This treated each yearly data independently.

In both villages, the households (farmers) were sampled through simple random sampling whereas, all farmers had equal chances to be selected. This sampling selected 10% of all farmers in the selected village. Thereby, a total of 400 farmers were sampled for interviews through the questionnaire, where each village—Mnyakongo and Ugogoni—involved 200 respondents. Farmers were orally interviewed in their respective households. They were asked numerous aspects focusing on the five over-arching questions posed in the introduction of this paper. Both structured and open-ended questions were tabled before the respondents. This allowed the acquisition of both objective responses and opinions. Apparently, this type of questioning was applied in questionnaires, discussion and informative interviews. Qualitative information was screened to omit the raised discrepancies. Thus, both objective and subjective responses were well handed.

Preliminary questions were aimed at exploring the general understanding of the people toward environmental change and the level of confidence to associate these change with agricultural production and the environment and the adaptation and mitigation measures that have been taken to improve their livelihood systems.

Respondents were also asked to give specific examples of environmental degradation and their specific impacts on their livelihoods. Similarly, they were asked if the governing policy gives any guidelines about the adaptation and mitigation (e.g., climate smart) in their livelihood activities. Third, through open-ended and non-prescriptive questions, respondents were asked to describe how they perceive the inter-relationship between climate change, environment and livelihoods.

Similarly, crop yields data from 1995 to 2015 were collected from District Agricultural and Livestock Officer (DALDO) and Ministry of Agriculture to evaluate the general production trend. The study collected considerable yields data for a time frame of between 1995 and 2015 because the Kongwa District was established in 1995 (formerly it was part of Mpwapwa District), thus, there were no recorded yields data for Kongwa beyond 1995.

The data on the availability of biophysical resources such as arable land, irrigable land, rivers, vegetation and altitudes just to mention a few, were solicited during data collection. Here, technical information from DALDO, Zonal Irrigation Engineers and District Foresters just to mention a few, were adequately consulted to acquire the biophysical data in their respective department. In addition, farmers were also requested to give their views (i.e., especially during discussion). Their knowledge helped to enrich the discussion section of this paper.

The DALDO also served as a reliable source for data related to the major livelihoods of the people in the study district. Other data were also collected from the farmers during interviews and discussion. Thereby, despite the generalization; that agriculture accounts to about 90% of the total livelihoods of Tanzanians, this study collected such data to sort out the contribution of various aspects to the livelihood in the area. Here the study focused on various crops and animals that serve as major livelihoods in the area and it used percentages to rank the contributions of each aspect.

Theoretically, the level of vulnerability was assessed depending on the farmers' response. Questionnaires had sections that solicited information on the vulnerability. Here the farmers were required to use percent to determine the level of vulnerability. Therefore, the magnitude (in percent) of the vulnerability was determined by the farmers' response and the information from the DALDO.

2.3. Data and Statistical Analyses

The Mann-Kendall Test with SPSS V20 and Microsoft Excel was used to analyze the mean annual variability of both rainfall and temperature. The annual rainfall and temperature data were coded in the excel sheet of the Mann-Kendell Test to enable the analyses. Both 95% and 99% of confidence levels were used in determine the trend analyses. Besides, crop yields data were analyzed through Microsoft excel. *P*-values less than 0.05 were supposed to be statistically significant ($P < 0.05$). Similar, most quantitative and qualitative data were presented in tabular form for easy reading. This type of presentation gives precise visual operation to the readers. Moreover, a bunch of qualitative data were analyzed through theme content method and the summaries were inserted in the text during discussion.

For more clarifications, the theme content analysis is among the most common forms of analysis in qualitative research [13–19]. It emphasizes pinpointing, examining and recording patterns (or "themes") within data. Themes are patterns across data sets that are important to the description of a phenomenon and are associated to a specific research question. Theme content analysis is best thought of as an umbrella term for a variety of different approaches, rather than a singular method. The approach to thematic analysis is performed through the process of coding in six phases to create established, meaningful patterns [20–26]. These phases are: *familiarization with data, generating initial codes, searching for themes among codes, reviewing themes, defining and naming themes and producing the final report.* Thereby, researchers of the present study were familiar with the main theme of the study and thus, qualitative information from the farmers were organized to produce a summery that enriched the discussion of this paper.

3. Results

3.1. Characteristics of the Respondents

Demographic characteristics of the respondents (household heads) were analyzed to justify the validity of data. The result in Table 3 indicates that the majority respondents were aged 41–60, whereas most of them had basic and secondary education (~90%) enough to respond to various research questions. Likewise, most respondents (~60%) were farmers who spent over 20 years in farming activities. All farmers were either crop producers, livestock keepers or doing both (mixed farming). These demographic characteristics were adequate to produce appropriate and relevant responses.

Table 3. Demographic and Farming Characteristics if Respondents in the Sampled Villages.

Variables	Percentage
Age	
i. 18–33	7.2
ii. 34–53	25.5
iii. 54–73	60.5
iv. >73	6.8
Sex of the Household Head	
i. Male	62.8
ii. Female	37.2
Marital Status	
i. Married	90.3
ii. Single	7.7
iii. Divorced/Separated	2.0
Level of Education	
i. Primary	72.3
ii. Secondary	20.2
iii. Post-secondary certificates	4.1
iv. University	3.4
Experience in farming	
i. 10–19	40.2
ii. 20–39	55.3
iii. ≥40	4.5
Agricultural practices	
i. Crop production	60.5
ii. Livestock keeping	10.2
iii. Mixed farming (i.e., crop and livestock)	29.3
n	400

Source: Field Data Survey, 2016.

3.2. Available Biophysical Resources and the Major Livelihood Activities in Kongwa District

Biophysical resources determine the livelihood systems in the area. It is obvious that people shape their life and obtain their needs basing on the available resources and level of entitlement. The result in Table 4 below shows the dominant biotic and abiotic resources that shapes the livelihoods of the people in the area.

Table 4. Main Biophysical Resources in the Sampled Villages.

Type	Quantity	References
Availability of arable land	363,690 ha	DALDO * 2016
Presence suitable land for irrigation	5811 ha	DALDO 2016
Availability of small rivers	See Figure 1	Arc GIS
Rainfall range	400 and 600 mm	TMA *
Temperature range	18 °C and 34 °C	TMA
Vegetation (mainly bush or thicket type)	-	DALDO
Altitudes (Mainly lowlands that is, 900 m a.s.l.)	3000 km^2	FAO-UNESCO

* DALDO-District Agricultural and Livestock Development Officer.* TMA-Tanzania Meteorological Agency. **Source:** Field survey Data, 2016

Besides, the major livelihoods are the life systems which are affiliated in social, economic and ecological development [1]. Among other things, the resources (Table 4) can determine the type, quality and quantity of the livelihoods systems. The result in Table 5 below indicates that agriculture (crop production and livestock keeping are the major livelihood systems in the area. They have significant contribution to social, economic and ecological development and therefore, when these activities are affected, the people's livelihoods become vulnerable [1,6–9]. For instance, they provide food, income and socio-economic entitlements. They determine both resilience and vulnerability of the people [16].

Table 5. Major Livelihoods in the Sampled Villages (i.e., expressed in different dimensions).

Livelihood activities	*Mnyakongo*	*Ugogoni*	*Count*	*Sum*	*Average*	*Variance*	*STDEV*
Maize	80	70	2	150	75	50	7.071068
Sorghum	70	66	2	136	68	8	2.828427
Millet	55	47	2	102	51	32	5.656854
Peas	23	17	2	40	20	18	4.242641
S. Potatoes	21	17	2	38	19	8	2.828427
Beans	12	14	2	26	13	2	1.414214
Sunflower	11	7	2	18	9	8	2.828427
Groundnuts	8	8	2	16	8	0	0
Sesame	4	4	2	8	4	0	0
Chicken	47	35	2	82	41	72	8.485281
Cattle	32	22	2	54	27	50	7.071068
Goat	26	14	2	40	20	72	8.485281
Sheep	12	8	2	20	10	8	2.828427
Donkey	6	8	2	14	7	2	1.414214
ANOVA *							
Source of Variation			*SS*	*df*	*MS*	*F*	*P-value*
Rows			14,030.86	13	1079.297	90.52166	1.5E-10
Column			175	1	175	14.6774	0.0021
Error			155	13	11.92308		
Total			14360.86	27			

* Anova: Two-factor without replication. **Source:** Field Data Survey, 2016

As an example, the production trends of the major crops were inspected to check whether they were affected or not. Figure 3 indicates that the production trends (tn/ha) have been turbulent due to environmental change. The pattern of this production trend is similar to that of rainfall (Figure 4). This notion was also captured in Table 6. Thus, this reveals that there has been a correlation between climate variability and crop production ($p < 0.05$).

Table 6. Vulnerability Levels in the Sampled Villages (Combined).

Variable	Magnitude/Level	Percentage of Impacted Village
Crop production	very high	Mnyakongo (70%), Ugogoni (80%)
Livestock keeping	high	Mnyakongo (60%), Ugogoni (75%)
Water sources	high	Mnyakongo (45%), Ugogoni (30%)
Soil fertility	moderate	Mnyakongo (30%), Ugogoni (20%)
Soil erosion	moderate	Mnyakongo (20%), Ugogoni (25%)
Vegetation	moderate	Mnyakongo (10%), Ugogoni (15%)

Source: Field Survey Data, 2016.

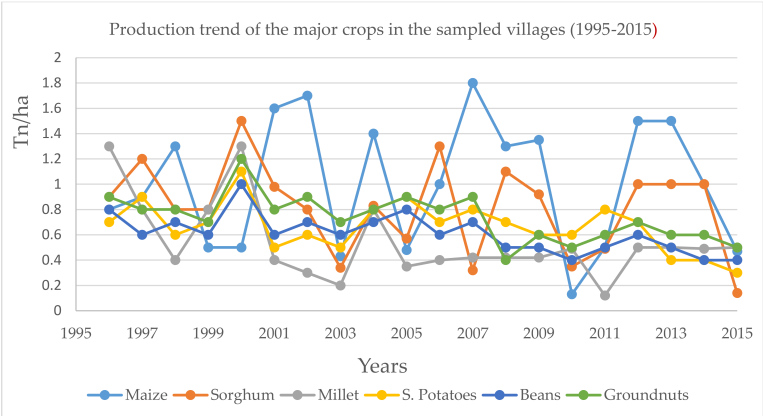

Figure 3. Production trend of the major crops in the sampled villages. **Source:** Adapted from Mkonda and He [17].

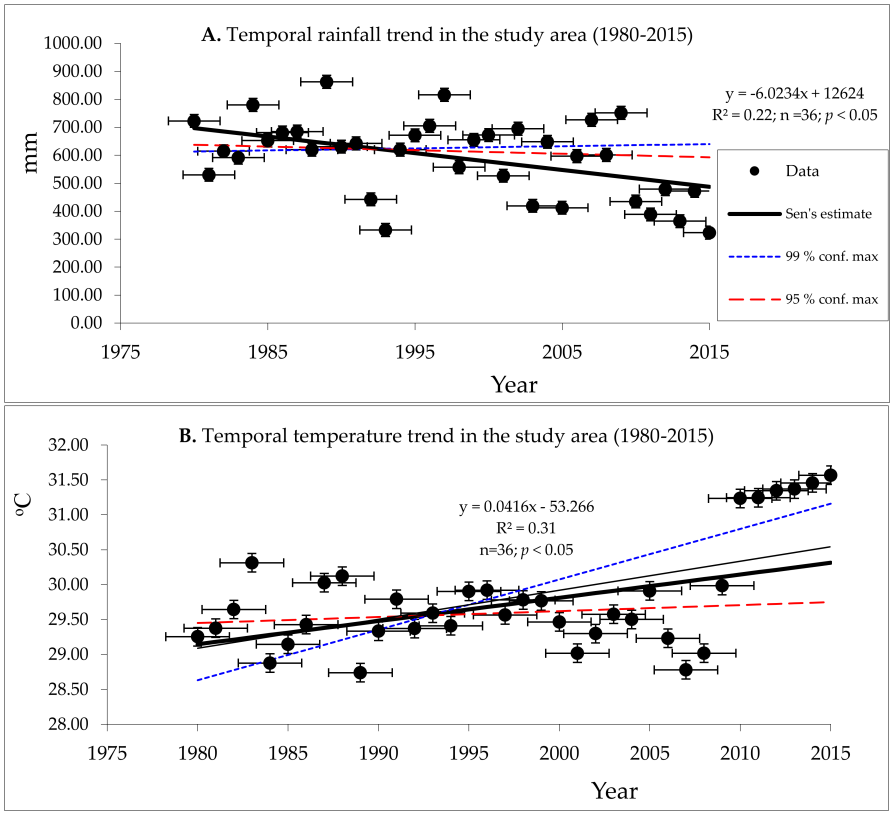

Figure 4. A combined climate variability in the sampled villages; rainfall (**A**) and temperature (**B**). The legend inserted in (**A**) equally represents (**B**).

3.3. Climate

Rainfall and temperature were the main concern in the sampled villages. The mean annual rainfall and temperature were observed to have been fluctuating in a decreasing and increasing trend respectively (Figure 3). This had ecological implication at local condition given that more than 90% of agriculture is rain-fed. In addition, this had implication to other aspects of the environment such as vegetation, water sources and other soil biological processes.

3.4. Effects of Climate Change to the Livelihoods

Climate variability has been affecting livelihood systems at national and local levels for a long time [10,11]. Despite the differences in magnitudes, various studies, including the present study, reveal that crop production and livestock rearing have been the biggest victims of this change (Table 6). This has been more pronounced in the semi-arid zone of Tanzania (area of the present study) where most livelihood systems have already been adversely affected. Moreover, these impacts have also dried up water sources and degraded soil fertility since most soil biological processes are affected by harsh weather and have slightly affected the artificial and natural vegetation.

Qualitative data from the farmers indicated that thousands of hectares have been deserted from agricultural production due to unproductivity (Table 7). The deserted hectares were expected to be reused if strong adaptation measures such as irrigation and fertilization were to be fully developed.

The level of vulnerability in both villages was relatively high. However, Ugogoni was more vulnerable in crop production and livestock than Mnyakongo (Table 6), while the latter was more vulnerable in water sources and soil fertility than the former.

Table 7. Estimated Abandoned Land (ha) Due to Unproductivity in Kongwa District.

Year	Maize	Sorghum	Millet	Groundnuts	S. Potatoes	Sunflower
1995/1996	850	350	90	70	100	60
1996/1997	800	300	80	70	100	60
1997/1998	850	310	90	80	110	50
1998/1999	900	350	100	90	120	80
1999/2000	1200	380	130	110	130	110
2000/2001	1300	500	180	120	150	120
2001/2002	1400	600	210	120	160	130
2002/2003	1400	700	180	170	200	130
2003/2004	1400	800	180	170	200	130
2004/2005	1400	800	160	150	250	125
2005/2006	1450	950	150	120	300	120
2006/2007	1300	790	230	209	230	126
2007/2008	2400	1100	160	280	209	136
2008/2009	2500	1150	380	140	390	140
2009/2010	3200	1200	290	230	280	145
2010/2011	2030	850	470	250	380	150
2011/2012	2300	980	309	260	380	160
2012/2013	3050	990	230	280	320	170
2013/2014	3500	1150	290	210	320	120
2014/2015	3800	1250	320	240	320	120

Source: Field Survey Data, 2016.

3.5. Sustainable Measures Undertaken

As ways of curbing the situation or reducing the vulnerability, the farmers have been adopting some measures that are practical in their area. Application of manure, drought resistant crops, crop rotation and conservation tillage were observed to be dominant in the area regardless their usefulness [25].

4. Discussion

The main theme of this section is based on the responses to the five over-arching questions (posed in the introduction) of this paper. Explicitly, these questions are addressed in three major aspects, namely; (a) Strengths/weaknesses/uncertainties of the data basis and methods of data collection, (b) Relevance/comparability/divergences of the results compared to similar studies in Sub-Sahara Africa, (c) Potential adaptation measures to reduce the vulnerability/improve food and water security.

To understand the farmers' knowledge on climate change and its impacts as a whole, there should be proper methods involved in that investigation. This may involve the competency of researchers and the level of farmers' participation in the research process. Furthermore, this may involve the instrument employed in that research such as automated weather stations (AWS) and the skilled personnel. Practically, this will to determine the reliability of climate data [16–18]. Thereby, the installation of AWS in various zones is quite imperative as it ensures the reliability of the data.

For example, the WASCAL (West African Science Service Centre on Climate Change and Adapted Land Use) and the SASSCAL (Southern African Science Service Centre on Climate Change and Adapted Land Use) are good examples of emphasizing authentic climate data through strengthening weather stations (i.e., AWS) within the collaborating countries. This is a bit different in some countries in which the installation of AWS is yet to be a practical idea.

The findings of the present study (actually and other several studies from Sub-Sahara Africa) reveal that people notice the impacts of environmental change in their areas, whereas, some attempt to adapt either by using drought resistant crops, squeezing into small scale irrigation (which always not adequate) or fertilization just to mention a few. While some farmers switch to other sectors such as business and casual labor, the majority are severely affected as lacking important resilience assets especially financial capital.

In addition, this empirical study has realized that most rural farmers are vulnerable to climate change. This happens because their major livelihoods have been extensively impacted by climate change impacts and are also undergoing serious degradation. This vulnerability is elevated by social, economic and ecological development stresses [12]. These results are in agreement with other studies that have been conducted in Tanzania [6–8]. Therefore, there should be proper intervention measures to limit the vulnerability.

Since semi-arid areas are among the most vulnerable agro-ecosystems in the country, the case study region experiences intensive impacts when further exerted into stress. While their livelihoods were observed to be vulnerable, most respondents had limited information on the existence of relevant policies responsible for environmental issues. This portrays that the creation of awareness related to environmental policy among the rural dwellers is considerably required.

Actually, poverty and shortage of extensive environmental knowledge have significant contribution to environmental degradation. Hardin [5] established that poor people whose livelihoods entirely depend on environment, can be the most important degrading agents of such environment when seeking to support their life. They can continue stressing the already affected environmental resources in search of livelihoods while the same environment cannot further support their life but it essentially needs restoration. Thereby, mutual interaction between man and the environment is equally advocated.

Despite of having hundreds of hectares of arable land (363,690 ha) in the case district (Table 4), this study has found that the livelihoods of the majority is uncertain. It is evident that over 70% of the people in the study area are engaged in crop production and livestock (see Table 5) as their main livelihoods, however, these are among the most affected sectors by climate change impacts and other global environmental changes as seen in Table 6. To give specific example, result in Figure 3 indicates that the trend of crop production has been declining as that of rainfall (Figure 4). This declining trend indicates that there have been some factors—especially rainfall—that considerably affected it.

The results from discussions indicated that most people aged above 40 had more references when explaining on the production turbulence compared to those below 30 years [18]. They clearly specified

that the unreliability in the onset and cessation of rainfall is the major aspect of climate variability that always affecst crop production and other dependable livelihood options in their locality.

Since climate change impacts also affect the biological processes of the soil (i.e., leading to soil unproductivity), it was realized that there has been a tendency of abandoning/deserting some unproductive agricultural land (Table 7). Furthermore, this deliberate deserting of unproductive land led to a concentration of fertile (productive) lands on which agricultural production is still promising, however, these lands are inadequate. Overall, both the farmers' livelihoods and the environment have been simultaneously affected by climate change impacts.

To reduce the vulnerability and improve food and water security; potential adaptation measures should be undertaken. The discussion on what are the best ways of adapting to climate impacts is still ongoing [19]. However, at the policy level (i.e., in Tanzania), slight measures have been established to intensify the resilience among the victims in the country. These include; the emphasis on drought resistant crops, irrigation and engagement in more socio-economic activities to increase income, just to mention a few. Unfortunately, these measures are inadequate to limit harsh situations, thus making future prospects less determined. Generally, the level of vulnerability of most livelihoods is yet to be controlled.

The results in Table 8 show the existing adaptation strategies to reduce the vulnerability of livelihood systems and the environment at large. Despite the application of manure, adoption of drought resistant crops, crop rotation and conservation tillage being highly vetted as adaptation measures, there is a need to expand the livelihood opportunities by creating or advancing more adaptation and mitigation measures [18,25]. Various recommendations from the conference of the parties (COP) and a series of IPCC reports recommend that large scale mitigation of climate impacts have sound results compared to the small scale, however, small scale adaptation measures (especially indigenous knowledge) are encouraged [2,19–21].

Table 8. Strategies Adopted by the Local People to Improve Livelihoods and Environment.

Measure	Mnyakongo (n = 200)	Ugogoni (n = 200)	Total (n = 400)
Application of manure	55	60	57.5
Drought resistant crops	45	50	47.5
Crop rotation	40	35	37.5
Little tillage	40	30	35
Adoption of agroforestry	35	25	30
Small scale irrigation	15	12	13.5
Chemical fertilization	6	8	7
Fallowing system	7	5	6

Source: Field Survey Data, 2016.

In the context of the study area and Tanzania as a whole, the failure in the agricultural sector has an overwhelming contribution in elevating poverty levels [16–21]. This is because over 80% of rural livelihood is entirely dependent on agriculture [2]. Despite being stipulated in various policies, plans and programs to downscale the level of poverty, especially in rural areas, through the optimization of crop yields, it is obvious that this aim may not be successful because the agricultural sector in most rural areas is increasingly dwindling. In such conditions, it is anticipated that a further increase in poverty levels may happen. To be rational, it is not worth buying the idea of Saint Thomas Malthus of reducing the population through positive and negative checks in order to reduce poverty—thus far, there is a need to deliberately boost marginalized societies through improving production systems.

If this is not dealt either at national, regional or local levels, there should be no expectation for the donor funded projects to do all responsibilities of improving the people's welfare. Now that, this is a responsibility of both the government and communities to do so. At the family level, if affordable, there should be a long-term plan on how to meet basic needs using the environment without hampering it or compromising future needs. [14]. Again, the government must set presidency on how to control

and utilize environmental resources for the betterment of the people, meeting present needs without compromising the needs of the future generation.

Principally, for a sustainable environment, "human-environmental interactions" or "social-ecological systems" should be mutual in nature. There should be good practices that is, getting needs and services from the environment while conserving it. Under the climate change scenario, this mutual interaction operates in the forms of adaptation and mitigation measures. The government of Tanzania and other local and international organizations have apparently championed this motion. For example, WASCAL and SASSCAL are good examples in equipping the respective communities against climate change impacts [22–24].

WASCAL tackles climate challenge by enhancing the resilience of human and environmental systems [24]. Among other things, it does this by strengthening the research infrastructure and capacity in West Africa related to climate change and by pooling the expertise of the collaborating countries. Similarly, it provides science-based advice to policymakers and stakeholders on climate change impacts, mitigation and adaptation measures.

Besides, SASSCAL has been doing relatively similar roles as that of WASCAL but in different regions (i.e., the southern part of Africa) [22,23]. It has been addressing various climate challenges mainly in food security, water security, declining and threatened biodiversity, deforestation and degradation of forests and providing climate services in the collaborating countries. Some of its specific roles include: Climate Data Management System (CDMS) and the development of capacities and associated training in the collaborating institutions.

It is anticipated that SASSCAL-supported research will improve the understanding of climate and land management change impacts on the natural and socio-economic environment within the southern African region [22–24]. All research supported by SASSCAL will provide scientifically sound knowledge for improving national, regional and broader international efforts to address adaptation and mitigation strategies [22–24]. Thereby, this will equip SASSCAL to provide services and develop products as needed by the end-users.

The results form WASCAL and SASSCAL are closely related to those advocated by the Tanzanian government and other developing countries. The main variation is the location, scale and level of funding. While WASCAL and SASSCAL are mainly funded by the German Federal Ministry of Education and Research (BMBF), Tanzania depends on a few organizations such as the International Institute of Tropical Agriculture, which is multidisciplinary in nature. Similarly, the government fund is always insufficient to support intensive adaptation to climate change impacts. As a result, there has been increased vulnerability, despite being aware of it.

Practically, this study has realized that the implementation of the strategies stipulated in Reference [8] above need full support from either the government or any reliable agricultural development partners. This is because most local people are facing economic difficulties and thus, they are incapable of implementing any sound adaption measures due to such financial constraint. Consequently, there is the need to build stable and sustainable economic capacity among the farmers.

Otherwise, these farmers will be subjected to further climate change impacts, as documented by Dassai et al. [15]. In addition, environmental and agricultural experts need to be readily available to provide advice, train and guide the farmers, as most farmers have little knowledge on essential agronomic issues. The interview with the District Agricultural and Livestock Development Officer (DALDO) revealed that the study district has insufficient extension officers to serve the farmers. Therefore, it is the responsibility of the local and central government to solve this crisis for the agricultural sector.

Given this vulnerability, it is advised that local communities in most rural areas of Tanzania (actually and other developing countries) should be given sufficient economic capacity and education to limit their vulnerability. This could strengthen adaptation and mitigation measures at a local level as a response to climate change impacts and other global environmental changes. To be realistic, capacity building and education should feature even at international for a, for example, in the conference of the

parties (COPs) and during the preparation of various IPCC reports. If no sound adaptation measures are to be taken, it is clear that most marginalized communities will continue to suffer and be under the utmost stress. Eventually, this will not only limit the availability of people's livelihoods but also the possibility of enjoying the live environment. And if this happens, the life cycle of the man-environment interaction will significantly diminish and probably come to an end.

5. Conclusions

This study has identified some key lessons to share with other researchers. Firstly, most farmers are aware of the impact caused by climate change, however, their level of resilience to withstand the impacts is very low. Secondly, the level of farmers' vulnerability depends on the nature of livelihoods. In the case of this study, it was realized that most farmers were vulnerable because their livelihoods entirely depend on agriculture (crop production and livestock keeping), which is susceptible to climate stress. Thirdly, their level of understanding of environmental policy was relatively inadequate. Fourth, their adaptation measures and coping strategies are barely useful. Theoretically, there has been a discrepancy between the magnitude of impacts to be curbed and the capacity invested for that adaptation. The former supersedes the latter. Ideally, this weak capacity is a fault of stakeholders, that is, farmers, government, funders and so forth. Thus, there is a need to resolve this discrepancy by strengthening the required instruments for adaption. Similarly, there is a need to soundly address all key issues related to climate in policy and other governance mechanisms. There should be the involvement of a wide range of stakeholders throughout the design and implementation of various initiatives, projects, programs and policy. At least, this will determine the way forward to limiting the overwhelming climate impacts in most developing countries.

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