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Assessing the Influence of Climate Change on Cashew Pests and Diseases and Adaptation Strategies of Farmers in Mtwara District, Tanzania

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Abstract
The main concern of the globe is the consequences associated with the climate change while more serious impacts of climate change are experienced in Agriculture. Under climate change, it is expected that the prevalence of crop pests will also change. Tanzania is the large cashew (*Anacardium occidentale* L) producer ranking 8th worldwide and 4th in Africa on cashew farming producing between 10-18% of the national per capita income yearly. However, the cashew's pests and diseases in Tanzania are increasing over time, while little is known whether the cashew's pests and diseases are influenced by climate change. The study conducted in Mtwara rural district to assess the trend of climate change, how climate change influences cashews' pests and diseases and strategies employed by farmers to minimize the impact. Questionnaire survey, key informant interview, focus group discussion and non-participant observation were used to generate information. Data from Tanzania Meteorological Agency show increase in temperature, rainfall and relative humidity. Such increase has influenced the increase of pests and diseases on cashew production. For instance, powdery mildew has continued to be increase, due to the increased temperature and relative humidity. There are also new cashew diseases which are associated with climate change such as Fusarium wilt disease (*fusarium oxyporum*) that was noticed in 201. This disease associated with the increase of the global temperature and rainfall along the coastal areas. A farmer has been employing different strategies to cope with the increase of pests and diseases. However, there are several factors hindering the adaptation process such as low capital and level technology and inadequate agricultural extension services. Policy option is recommended include the availability of credit, subsides for farm inputs and proper information such when and how to control pests and diseases by using pesticides and insecticides

Keywords: Climate change, Cashew nuts, pests, diseases

Introduction

Climate change is widely recognized as a major environmental challenge facing the globe (UNEP, 2009). This is evident from the warmer temperatures observed across the world over the last few decades, with a more rapid warming trend during the latter half of the 20th century compared to the past (Padgham, 2009).

The rate of warming increased in the mid-1970s, and each of the most recent three decades has been warmer than all preceding decades since 1850. The primary concerns regarding climate change are the associated consequences. Africa has been identified as one of the regions most vulnerable to the impacts of climate change (IPCC, 2014). According to the IPCC's 4th Assessment Report, there is evidence that Africa is warming faster than the global average, and this trend is likely to continue (IPCC, 2007; AMCEN, 2011).

The most severe impacts of climate change are experienced in the agricultural sector. The IPCC's Fifth Assessment Report states that changes in the climate over the last 30 years have already reduced global agricultural production by 1 to 5% per decade compared to a hypothetical situation without climate change (Dinesh et al., 2015). In East Africa, for example, outbreaks of certain pests such as cereal aphids and coffee berry borer have become more frequent in recent years (Dinesh et al., 2015).

As a developing country, Tanzania is more vulnerable to the impacts of climate change due to its reliance on climate-sensitive activities such as agriculture (Lavera, 2009). The Tanzanian Ministry of Agriculture, Food Security and Cooperatives (2014) has noted that the emergence of new pests and diseases in geographical areas where they were previously absent is suspected to be an indirect impact of changing weather conditions. Under climate change, the prevalence of crop pests is also expected to change, with increased frequency of new pest introductions, major pest outbreaks, and risks of pesticide residues in food (Dinesh et al., 2015)

As a sign that farmers have started experiencing the impact, the study by Kidunda et al, (2013) explained that farmers are now changing from cashew production to sesame crop due to failure on their harvests caused by pests and diseases. The UNIDO (2011) also confirmed that pests and diseases threaten cashew nut production. However, none of the studies showed clearly the influence of climate change on cashew's pests and diseases and the strategies employed by farmers to minimize the impacts in Tanzania. The country is the largest cashew producer ranking 8th worldwide and 4th in Africa on cashew farming producing between 10-18% of the national per capita income yearly from cash crop sector (FAO, 2015). The Production has been fluctuating over a period (UNIDO, 2011,Eci Africa, 2003, ANSAF, 2012).

The available evidence from the Naliendele Agricultural Research Institute (NARI) in Tanzania, in the season of 2002/3 shows that the cashew disease is the most active during wet weather, especially during the off-season rains where severe infections affected the young flushing material. The surveys confirmed increase in fungal diseases throughout a region (CIGI, 2009). However, none of the study links the increase in incidence of pests and diseases in cashew nuts production with climate change in Tanzania and the strategies employed by farmers to minimize the impact.

A study conducted by Haggar and Schepp (2012), in India, showed that rain-fed cashew nuts is highly sensitive to climate change especially during the production phase. Variability and heavy dew during flowering and fruit period aggravated the incidence of pests and diseases (Datta, 2013) while cashew nuts farmers overcome the climate change impact by growing alternatives crops (Kidunda et al., 2013). However, in Tanzania there are still farmers growing cashew nuts though there is incidence of pests and diseases while the adaptation strategies are not well known. In addition, the impacts level of climate change depends on the climatic zones of each area (IPCC 2007). This means that farmers in different zones will experience the impact of climate change differently and will need different adaptation measures to cope with the changes (Mbilinyi et al., 2013).It therefore, invites for study to assess how climate changes contribute to cashew pests and diseases and the strategies employed by farmers to minimize the impacts in Mtwara Rural District of Tanzania.

Conceptual Framework

Climate change leads to change in temperature, rainfall and relative humidity in a given area. Temperature, rainfall and relative humidity have climate relationship modification for each other as indicated by arrow with two directions. (Fig 1). For instance, in coastal area, rainfall is sensitive to relative humidity and also temperature changes impact the number of hydrological processes such as rainfall and these processes, in turn, impact temperature which influences pests and diseases of various crops such as cashew. This is because; pests and diseases are influenced by change in climate parameters. Depending on the level of impact of pests and disease, cashew farmers have been employing various strategies to cope with the increase in pests and diseases. However, there are several factors that hinder adaptation strategies such as lack of enough technologies, poor extension, lack of enough capital, shortage of extension services etc.

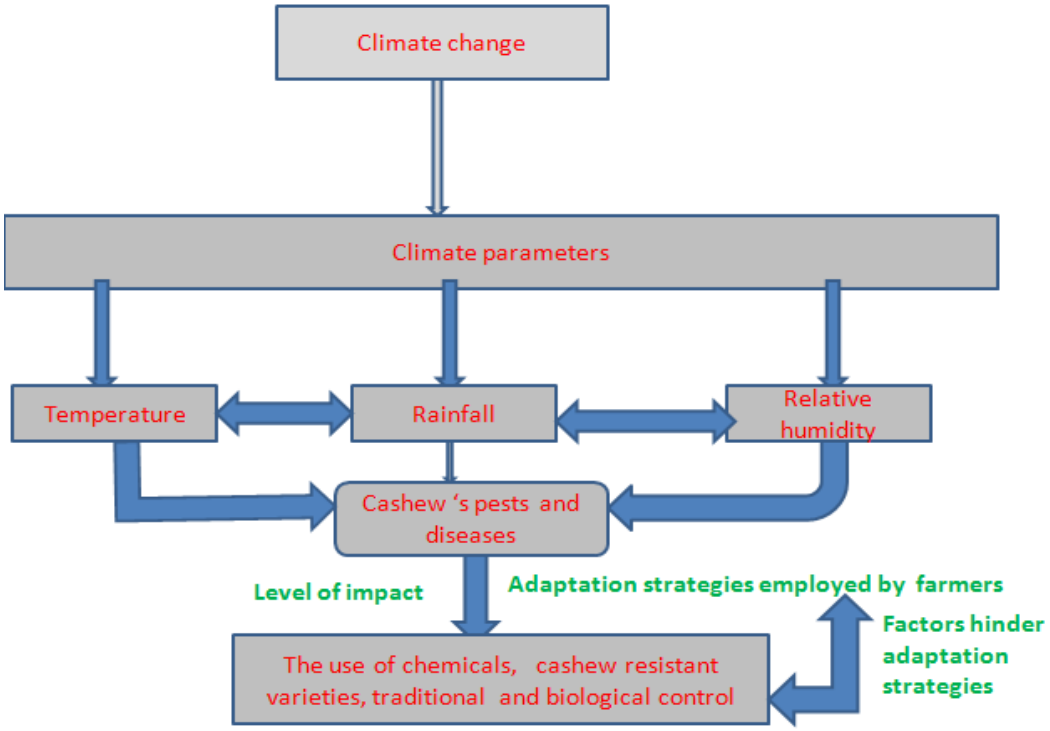

Figure 1. Conceptual framework of the study

Research Methodology

Description of the Study Area

Mtwara Rural District is located between latitude 10°25'48" S and latitude 10°96'27"S respectively. The study was conducted in two wards (Fig 2) and in each ward, two villages were selected randomly. Therefore, the study was conducted in four villages namely Nitekela, migombani, Ntemba and Nanguruwe. Mtwara Rural district was selected for study based on its advantage of being the greatest producer of cashew nuts in the country and therefore was appropriate to generate the data needed for the study. According to Cashew nut Board of Tanzania (CBT), Mtwara region covers about 35% of the total land for cashew cultivation and it is greater than Lindi (28%) and Ruvuma (14%).

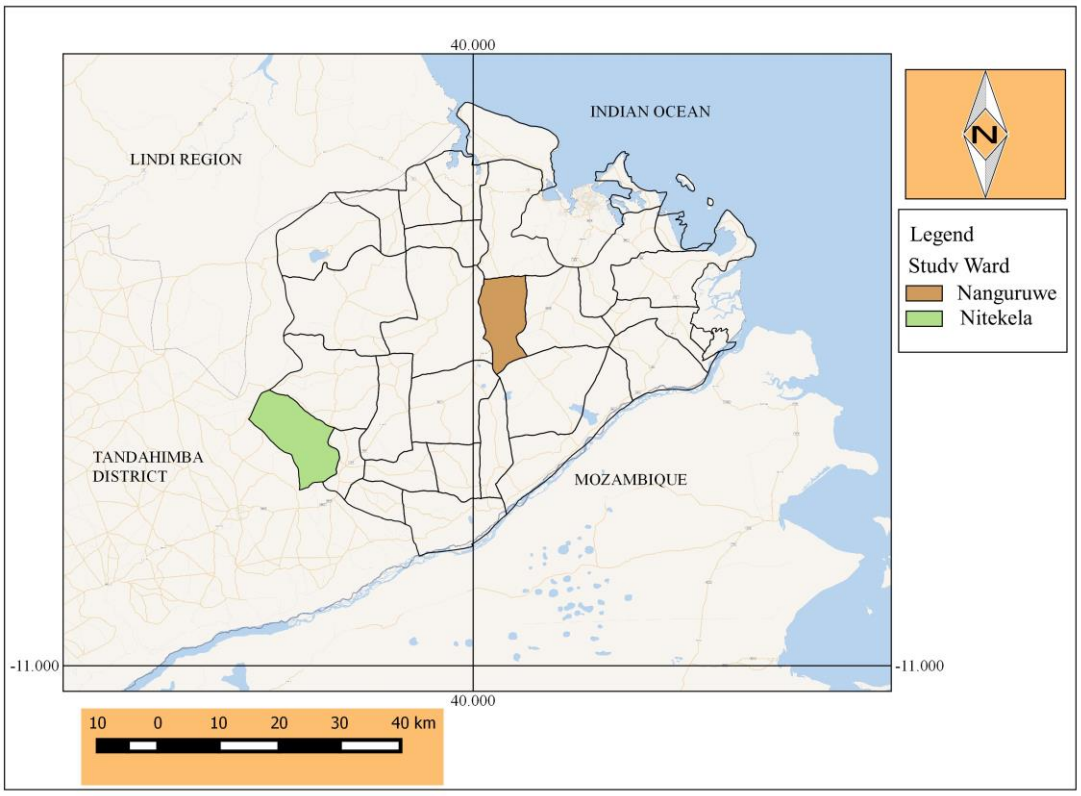

Figure 2: Topographical Map of Mtwara district showing study area

Data Collection Methods

Data were collected from primary and secondary sources. The primary data were collected directly from the field through questionnaire surveys, interview with the key informants, focus group discussion and field visits while secondary data were collected through documentary review. Simple probability sampling was used to select farmers for questionnaire survey. Sample size was obtained using Yamane formula (Neuman, 2006). The formula gave a total number of 377 respondents from 5866 cashew famers' household available in the two wards. Non-probability sampling procedure was used to select key informants for interview such as village leaders, farmers' association group leaders, ward/village agricultural officers, primary cashew cooperative union leaders and researchers from Naliendele Agriculture Research Institute Rural District. The aim was to generate the information regarding pests and diseases affecting cashew nuts production as well as strategies used to minimize the impacts. In addition, two focus group discussions were held to cashew farmers from each ward. The aim of focus group discussion was to get more information through farmer's discussion. In addition, non-participant observation was conducted to observe the real situation in cashew nuts farms and adaptation employed by farmers to reduce the incidence of pests and diseases. Documentary review was done by reviewing different published articles, official reserved data and books with the relevant data regarding the impacts of climate change to cashew pests and diseases and adaptation strategies.

Results and Discussion

Table 1: Distributions of Respondents in the Study Area

Ward	Villages	Number of Respondents per sex					
		Male	Male (%)	Female	Female (%)	Total	Total (%)

Nitekela	Nitekela	111	29	32	8	153	37
	Migombani	94	25	22	6	106	31
Nanguruwe	Nanguruwe	59	16	21	6	80	22
	Ntemba	32	8	6	2	38	10
Grand total		296	78	81	22	377	100

The information in Table 1 shows the total number of the respondents in the study area whereby 296 (78%) were males and 81 females (22%).The imbalance of gender representation in this study is a result of cultural and religious orientation. Traditionally, heads of the family are males and have been owners of the properties with authority to give details concerning the family matters even though they can grant such power to the rest of the family members.

Trend of Climate Parameters in Mtwara District within a Decade

The variations of climate parameters (temperature, humidity, and rainfall) within a decade were assessed. Meteorological data were obtained from Naliendele meteorological station in Mtwara district

Temperature

Figure 2 shows the mean annual temperature trend in the area of study from 2006 to 2016. The annual temperature pattern for one decade has been fluctuating over the time. However, the overall trend shows an increase in temperature within a decade. Through the linear regression model, (Fig 3) shows an increase of temperature over the past 10 years (y=-229.6627 +0.1264*x, R^2 = 0.33, P =0.063).

The interview conducted with the NARI meteorological department officer declared that, "***the temperature of Mtwara region has generally been increasing within the recent decade as station record shows upward trend. This could be promoted by the global warming in which areas near the oceans have been experiencing high temperature than it was in the previous years.*** This finding is supported by IPCC (2007) report which states that warmer temperature will be experiencing in the coastal parts of Africa which then will promote unexpected higher rainfall.

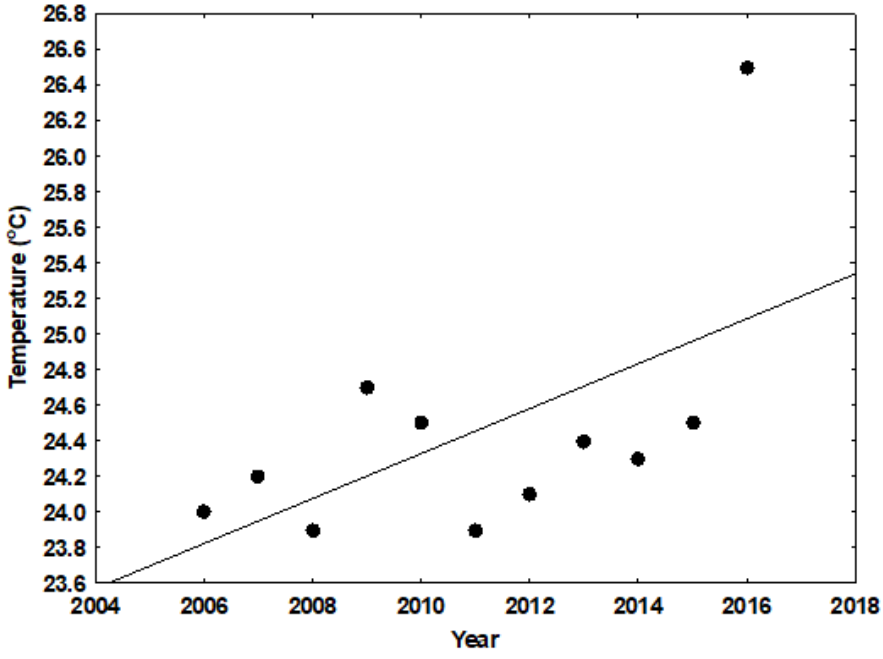

Figure 3. Annual Mean Temperature of Mtwara Rural from 2006 to 2016

Rainfall

The National Adaptation programme in Action of Tanzania over climate change, specifically to variation of rainfall revealed that there will also be an increase in rainfall in some parts while other parts will experience decreased rainfall. The predictions further show that the areas with bimodal rainfall pattern will experience increased rainfall of 5% – 45% and those with unimodal rainfall pattern will experience decreased rainfall of 5%– 15% (URT (2007). This situation has actually already been experiencing in some parts of the country especially to coastal zone of Mtwara, in which currently, the area experiences high annual rainfall than it was in the previous years. Figure 4 below shows the trend of rainfall in Mtwara District within the recent decade which indicates that the amount of rainfall has increased over a decade ($y=26.138*x-51547$, $R^2=0.0994$) (Fig 4). This observation is in line with the explanation by Otte et al (2017) who described that the increase of rainfall in East African coastal rainfall increase is linked with large scale ocean-atmosphere interactions, Indian Ocean Dipole (IOD) and El Nino-Southern Oscillation movements.

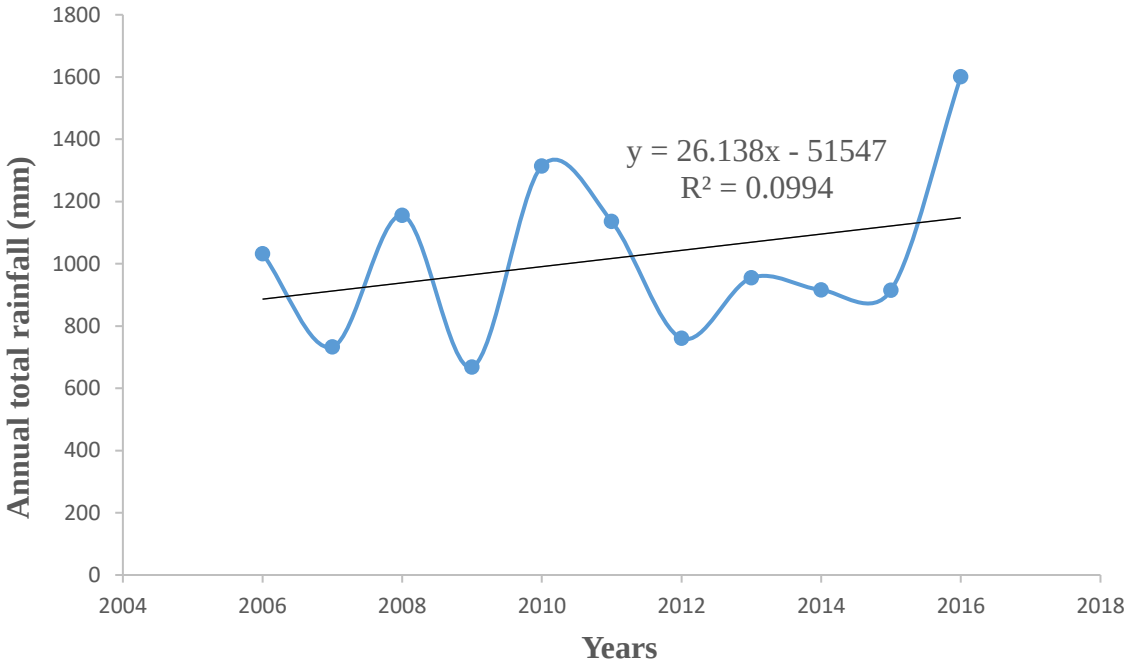

Figure 4. Mean Annual Rainfall of Mtwara District 2006-2016

Relative Humidity

Mtwara District is situated alongside the Indian Ocean and, therefore, the relative humidity has been influenced by the ocean water evaporation. Byrne and O'gorman (2016) described that, under climate change, continents warm rapidly than oceans. The rate of increase of the moisture evaporation from the ocean to land cannot step up with the faster increase in saturation specific humidity over land. Through Linear regression model (Fig 5), relative humidity in study area shows to have increased over decade ($y=0.2455x-0.763, R^2=0.076$).As the Mtwara district is situated along the coast, it has relative humidity increase which can be influenced by the temperature increase as promoted by climate change. These findings are in line with Sherwood et al (2010) who explained that the systematic change of the relative humidity is explained on the local situation through which trends and gradient of humidity at an area depend on the model's ability to resolve evaporation through the increased temperature.

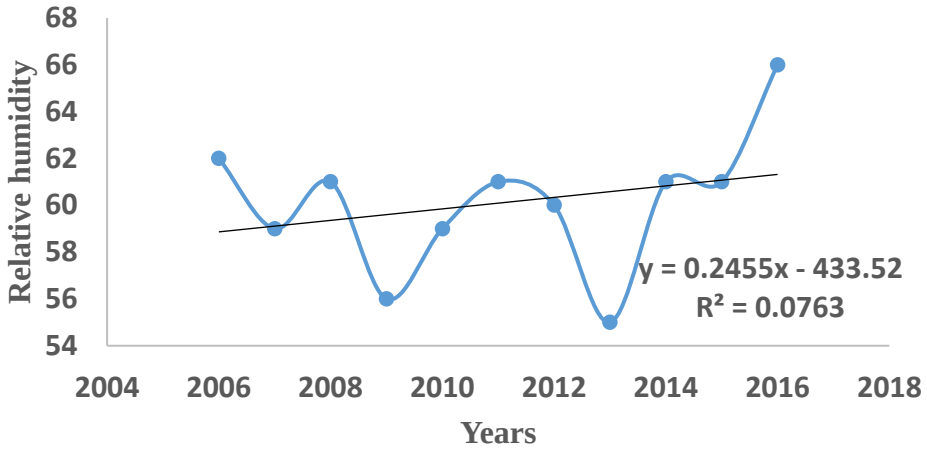

Figure 5: Relative humidity of Mtwara rural district 2006-2016

Farmers' Knowledge over Cashew Pests and Diseases

Farmers are primarily concerned with the presence of pests and diseases in their production. They are able to identify and take first action over the persisting diseases and pests. Hence, they even report new pests and disease to the agricultural extension officers. The majority of cashew farmers (84.9%) were familiar with pests and diseases occurring in cashew farming while only 15.1% of them were not aware of this. Furthermore, majority of farmers (90.2%) complained about the decrease in cashew nut production at individual level due to the increase of pests and diseases on individual farmer basis. The overall increased trend of production is probably due to the rise in cashew nuts price which motivates farmers to increase the size of their farms. New farmers are engaged in the production of cashew nuts and old farmers are still under expansion of farming plots. Contrary to individual cashew farming plots, the production rate per acre within a decade has been noticed to decrease and it is associated with increase in the cost of production due to increase in pests and diseases (61.5%), inadequate pesticides and insecticides (23.3%) and rainfall variation pattern (15.2%) (Table 2).

Table 2: Knowledge of Farmers on Cashew Pests and Diseases

Variables	Responses	Frequency	Percentage
Awareness of cashew pests and disease	Yes	320	84.9
	No	57	15.1
Causes of low yield per individual	Diseases/Pests	232	61.5
	Inadequate chemicals	88	23.3
	Rainfall variation	57	15.2

The Influence of Climate Change on Cashew Pests and Diseases

Regarding to this aspect, the aim was to investigate whether climate change has been influencing cashew nuts pests and diseases. This was done through assessment of rainfall, temperature and relative humidity in relation to specific diseases through discussion with farmers and key professionals. Mtwara District rural is among the cashew producing zones that has been experiencing different types of cashew nuts pests

and diseases such as powdery mildew disease (PMD), blight, anthracnose, die back and newly cashew wilt disease.

Powdery Mildew Disease (PMD)

Powdery mildew (*Oidiuman acardii*) disease is a weather sensitive disease in which higher relative humidity and temperature influence the incidence of diseases. It is doubtless that powdery mildew cashew disease is the most threatening disease to the crops. The results (Table 3) show that about 80% of the respondents complained about increased trends. This finding matches with trend of increasing humidity and temperature in the study areas. The finding is also in line with Salinari et al (2006) who reported the increase of downy mildew on grapes as a consequence of increase in temperature.

Table 3: Responses on Cashew Powdery Mildew Disease

Disease	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Powdery mildew	Slight	Frequency	10	5	6	3
		Percentage	6.5	4.7	7.5	7.9
	Moderate	Frequency	17	11	7	4
		Percentage	11.1	10.4	8.8	10.5
	High	Frequency	125	90	67	31
		Percentage	81.7	84.9	83.8	81.6
	No impact	Frequency	1	0	0	0
		Percentage	0.7	0.0	0.0	0.0
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Blight Cashew Disease

Recently, a new pathogenic fungus (*Cryptosporiopsis* spp) causing cashew blight disease has been reported in Tanzania (Dominic et al., 2014). In this study, blight cashew was mentioned by majority of farmers as one of the diseases which highly affect cashew production (Table 4). The head of the Department of Pathogenic Research at NARI had the following to say "*increased temperature within the decade has increased the incidence of blight cashew diseases in Mtwara district."*

Table 4: Responses on Blight Cashew Disease

Disease	Level of impact		Villages			
			Nitekela	**Migombani**	**Nanguruwe**	**Ntemba**
Blight	Slight	Frequency	34	23	8	2
		Percentage	19.5	21.2	12.0	11.8
	Moderate	Frequency	42	29	20	10
		Percentage	26.8	27.2	25.5	29.6
	High	Frequency	75	51	49	25
		Percentage	52.8	38.7	58.5	54.4

	No impact	Frequency	2	3	3	1
		Percentage	1.0	2.8	4.0	4.3
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Dieback Shots and Leaf Cashew Disease

These are diseases which are facilitated by the annual temperature between 23ºC to 28ºC with relative humidity ranging from 85% to 100% respectively (CIDTF & NARI, 2016). This similar to secondary data obtained from study area in which average temperature within all years was above 24°C. It was revealed that majority of the farmers (50.9%) explained that cashew dieback shots and leafs to slight infections to cashew nuts (Table 5).

Table 5 : Responses on Dieback Cashew Disease

Disease	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Dieback	Slight	Frequency	59	54	37	8
		Percentage	38.6	50.9	46.2	21.1
	Moderate	Frequency	44	25	18	12
		Percentage	28.8	23.6	22.5	31.6
	High	Frequency	14	4	7	5
		Percentage	9.2	3.8	8.8	13.2
	No impact	Frequency	36	23	18	13
		Percentage	23.5	21.7	22.5	34.2
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Anthracnose Disease (*Colletotrichum Gloeosporoides*)

Anthracnose was also another disease mentioned by majority of the farmers and it seems to affect crop at high level (Table 6). This finding is in line with Monteiro et al (2015) who reported anthracnose as the most important disease in cashew production leading to a significant loss of yield in Benin.

Table 6: Responses on Anthracnose Cashew Disease

Disease	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Anthracnose	Slight	Frequency	21	9	10	2
		Percentage	13.7	8.5	12.5	5.3
	Moderate	Frequency	7	15	8	5
		Percentage	4.6	14.2	10.0	13.2
	High	Frequency	65	51	31	20
		Percentage	42.5	48.1	43.8	52.6
	No impact	Frequency	60	31	27	11
		Percentage	39.2	29.2	33.8	28.9
	Total	Frequency	153	106	80	38

		Percentage	100	100	100	100

The influence of climate change on Cashew's Pests

Tanzania has been experiencing cashew pests in every production season. It was revealed that there is notable five common cashew pests which are cashew nut mosquito, coconut mosquito, stem borers, mealy bug and cashew aphids.

Coconut Mosquito Bugs

Coconut mosquito pest is an insect that attacks both cashew nuts and coconut crops. It is a brown-reddish like insect with greenish skin on stomach. The effects caused by coconut mosquito are similar to those caused by cashew nut mosquito (CIDTF & NARI, 2016). During interview with Ward Agricultural Officer, she argued that; ***"Historically, coconut mosquitoes firstly were attacking coconuts but in the current years, these pests have been attacking also cashew. This might be a transformation associated with climatic change in which they have developed some adaptation for them to feed on other sources."*** Coconut mosquito bugs are common cashew pests that farmers in the study area mentioned as the threat to their production. Majority of the farmers explained the coconut mosquito bugs as threat to cashew production. (Table 7). Similarly, Research Officer of NARI comment c; ***"Prolonged hot season encourages the coconut bugs to attack cashew crop. This season generally marked from September to January and sometimes in February"***. This finding complies with temperature data in the study area which show temperature increase.

Table 7: Responses on Coconut Mosquito Pests

Pest	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Coconut bugs	Slight	Frequency	20	11	9	4
		Percentage	10.4	10.2	12.2	17.1
	Moderate	Frequency	49	33	21	7
		Percentage	29.9	30.8	27.8	28.2
	High	Frequency	76	54	45	26
		Percentage	53.1	52.5	53.8	10.1
	No impact	Frequency	10	7	5	1
		Percentage	6.5	6.6	6.2	2.6
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Cashew Mosquito Bugs *(Helopeltiss.spp)*

The study conducted by Ewing et al (2016) over the modeling effects of temperature on the seasonal dynamics of temperate mosquitoes concluded that there is considerable evidence showing that the

environmental drivers have a large impact on both the life of the mosquito and transmission of diseases. Hence, as the temperature of the study area shows increase within a decade, cashew mosquito bugs will continue to increase their scale of threat to cashew nut production. As indicated in table 8 majority of the respondents explained that, cashew mosquito bugs have highly been affecting the production of cashew.

Table 8: Responses on Cashew Mosquito Pests

Pest	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Cashew mosquito	Slight	Frequency	25	19	12	5
		Percentage	16.3	17.9	15.0	13.2
	Moderate	Frequency	33	24	17	9
		Percentage	21.6	22.6	21.2	23.7
	High	Frequency	84	60	48	22
		Percentage	54.9	56.6	60.0	57.9
	No impact	Frequency	11	3	3	2
		Percentage	7.2	2.8	3.8	5.3
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Cashew Stem Borers

Unlike other cashew pests, stem borers have minor effects to the cashew stem as it is indicated in Table 9. Through Focus Group Discussion (FGDs), cashew farmers added that, stem borers are not a threat since they attack few of the cashew trees. This was emphasized by the research officer at NARI who said that the effect of stem borers is insignificant to the cashew production.

Table 9: Responses on Cashew Stem Borers Pests

Pest	Level of Impact		Nitekela	Migombani	Nanguruwe	Ntemba
Cashew stem borers	Slight	Frequency	63	44	33	16
		Percentage	41.2	41.5	41.2	42.1
	Moderate	Frequency	14	10	2	7
		Percentage	9.2	9.4	2.5	18.4
	High	Frequency	5	1	2	1
		Percentage	3.3	0.9	2.5	2.6
	No impact	Frequency	71	51	43	14
		Percentage	46.4	48.1	53.8	36.8
	Total	Frequency	153	106	80	38

		Percentage	100	100	100	100

Cashew Aphids (*Thrips Rubrocinctus*)

Aphids were also seen to be dangerous pests in the study area as majority of the respondents explained that there was a high infection rate in all villages (Table 10). Cashew aphids are much active during the dry season from June to October with hot temperature (CIDTF &NARI, 2016). During interview with Nitekela Ward Agricultural Extension Officer. He had the following to comment ***"Nowadays cashew aphids have been causing infections on large scale as dry season is prolonged to December which is quite different the way it was in the previous years".*** Since the Cashew Aphid is active in hot temperature,the trend is expected to increase since the trend of temperature shows to have been increasing.

Table 10: Responses on Cashew Aphids Pests

Pest	Level of impact		Nitekela	Migombani	Nanguruwe	Ntemba
Aphids	Slight	Frequency	18	11	10	6
		Percentage	11.1	10.3	13.0	19.1
	Moderate	Frequency	39	33	20	8
		Percentage	24.8	31.0	25.5	24.3
	High	Frequency	86	55	45	23
		Percentage	57.6	52.1	55.2	54.0
	No impact	Frequency	10	7	5	1
		Percentage	6.5	6.6	6.2	2.6
	Total	Frequency	153	106	80	38
		Percentage	100	100	100	100

Adaptation Strategies Employed by Cashew Farmers on the Control of Pests and Diseases

Majority of the farmers (57.2%) mentioned that chemical control (fungicides, bactericides, etc) was used to control pests and diseases followed by the use of traditional methods (25.6%). The use cashew resistant varieties to pests and diseases and biological control were also mentioned as other adaptation measures (Fig 7).

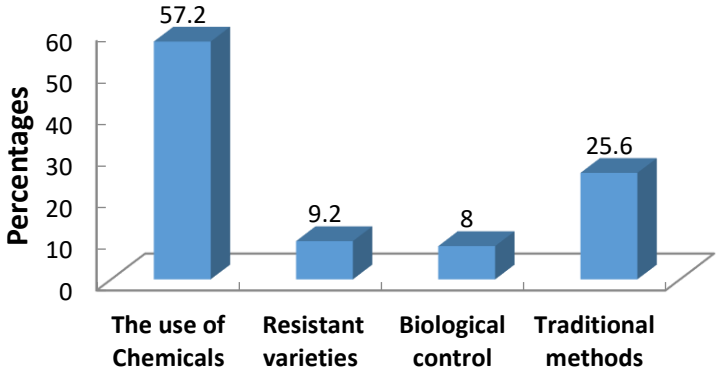

Figure 7: Adaptation Strategies used by Cashew farmers to control pests and diseases

Use of various chemicals (Fungicides, bactericides, pesticides, insecticides etc)

In previous years powdery chemicals were more acceptable than liquid form. However, currently, farmers have been mixing both liquid and powder. This was also explained by the Nitekela Ward Agricultural Extension Officer who said that; '***In previous years, farmers were using powderier than liquid form of chemicals. However, after several trials done by few cashew farmers, they realized that use the combination of both form of chemicals is more effective than single one."***

It was revealed that, farmers were getting chemical through government subsidies, buying them from private stores and others were through both subsidies and buying. However, majority of farmers (60.4%) revealed to have been obtaining them through buying from private stores (Table 13) but were complained that subsidies chemicals were insufficient; thus, making them decide to buy chemicals from private sector as an alternative to get enough chemicals to control cashew pests and diseases though are very expensive (Table 11).

Table 11: Farmers' ways of obtaining chemicals to control pests and diseases.

Variables	Frequency/Response	Percent(%)
Ways of getting chemicals		
Subsidies	24	5.7
Buying	144	34
Buying and subsidies	256	60.3
Total	424	100
Price of chemicals		
Cheap	60	15.9
Moderate	119	31.6
Expensive	198	52.5
Total	377	100

Biological Control of Cashew Pests and diseases

The study found that only few farmers were practicing biological control of pests and diseases. The biological methods mentioned were the use of weaver ants and Sangara[1] insects as to control the pests which were affecting cashew production. However, it was revealed that the Sangara had side effects on cashew quality since they have been producing mucus which sprinkled into blackish to cashew young nuts. However, there are other insects that control pests as they were mentioned by farm extension officers. These were spiders, small frogs, and chameleons.

Traditional Cashew Pests control

Cashew farmers were also controlling pests and diseases through pruning, barking, burning and uprooting the affected cashew tree before the application of chemicals. The pruning technique is the most common technique that farmers use to control pests and diseases. Barking on affected cashew tree stem is another technique to control stem borers pests.

[1]Sangara; Swahili name given to small insects found on cashew tree branches which feeds on cashew pests.

The use of Improved Cashew Seedling

The use of improved seedlings was another scientific adaptation tools to minimize the effect of pests and diseases. The improved varieties from Naliendele Agricultural Research Institute were distributed to the farmers. This institute produces those improved cashew seedling purposively to control cashew pests and diseases. The head of Department of Pathogenic Research at NARI substantiated that; "***The institute has developed climatic stress and disease adaptation cashew seedling project so as to adapt the ongoing climate change.*** He added that *several varieties of new cashew seedling were developed like* AZA_2 *and* AZA_{17} *resistant to blight cashew disease.* "However, majority of the cashew farmers of the farmers (76.4%) were not interested in the use of improved seedlings while only 23.6% preferred those improved seedlings.

Constraints that Hinder the Adaptation Strategies

There are several constraints that to some extent hinder the adaptation options. Among them are poor knowledge on appropriate adaptation strategies, mixing and proper method of using chemicals. In addition, cashew farmers do not have advanced knowledge on biological control. It was revealed that farmers remove some insects like weaver ants which were supposed to be placed all over the cashew tree for controlling pests. Nevertheless, chemical control is the barrier to this technique as most of the chemicals kill these potential insects like other pests.

Pruning of cashew branches is also accepted but farmers lack potential skills on how to do it. Therefore, some of the farmers do not follow rules during pruning.

There are also several constraints such as the price and choices of the chemical. Farmers complained about high price of the chemicals. In addition, the presence of different types of insecticides and pesticides in the market confuses farmers on the appropriate chemicals to choose in controlling pests and diseases. Farmers sometimes mix all liquid and powdery forms of chemicals without any concrete reason. Nevertheless, due to lack of education, farmers are not in position to determine appropriate chemical, time, frequency of chemical application and human risks associated with the chemicals and its precautions to take. There is also the lack of acceptability of the improved seedlings by majority of the cashew farmers in the study area. Other major challenges are lack of enough capital with which to buy enough pesticides and insecticide and knowledge to control new pests and diseases

Initiatives by Government to Control Cashew Pests and Diseases

Majority of the farmers (77.5%) revealed to have never received any training from the Government while 22.5% accepted to have attended few seminars. Majority of the cashew farmers (89.4%) declared that there were no agricultural extension services provided to them because the extension officers were located at ward and district level only. Few (10.6%) declared to have been receiving training on pests and diseases of cashew. Therefore, inefficient extension services have been leading to inappropriate use of chemical to control pests and diseases and other methods. Furthermore, farmers said to have been receiving subsidies of insecticides, pesticides fungicides and others from the government though these services were not provided on time and sometimes farmers were required to supplement the chemicals by buying others from the private shops.Farmers suggested measures to improve cashew nuts production including provision of the subsidies at appropriate amount and on time, provision of training to farmers especially application of chemicals to control pests and diseases. They argued that farmers needed information on how to mix the chemicals, the appropriate time of application and how to deal with new cashew diseases.

Conclusion

This study has revealed that climate change, particularly the increase in temperature, rainfall, and relative humidity, has significantly influenced the prevalence and incidence of pests and diseases affecting cashew production in Mtwara Rural District, Tanzania. The key findings show that the emergence of new cashew diseases like Fusarium wilt, as well as the increased severity of existing pests and diseases like powdery mildew, are directly linked to the changing climatic conditions. Farmers in the study area have employed various strategies to cope with the impacts of climate change on cashew pests and diseases. These include the use of pesticides, adopting early harvesting, intercropping with other crops, and diversifying income sources. However, the effectiveness of these strategies has been hindered by factors such as limited access to credit, low technological know-how, and inadequate support from agricultural extension services.

Recommendations

To enhance the resilience of cashew farming systems to the impacts of climate change, the following policy recommendations are made:

- Improve access to affordable credit and farm inputs (e.g., pesticides, improved cashew cultivars) to enable farmers to effectively manage pests and diseases.
- Strengthen the capacity of agricultural extension services to provide timely and relevant information to farmers on climate-smart pest and disease management practices.
- Promote the use of Integrated Pest Management (IPM) approaches that combine cultural, biological, and judicious use of chemical control methods to minimize the impact of pests and diseases.
- Invest in research to develop and disseminate climate-resilient cashew cultivars that are tolerant to pests and diseases.
- Enhance coordination between meteorological agencies, agricultural research institutions, and extension services to facilitate the timely dissemination of weather forecasts and advisories to farmers.

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