The role of on-farm trees as an adaptation strategy to climate change effects around Mkingu Nature Forest Reserve in the Eastern Arc Mountains, Tanzania

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ABSTRACT

A study was conducted to investigate the role of on-farm tree as a long-term and sustainable adaptation strategy to climatic stresses in eight villages around Mkingu Nature Forest Reserve (MkNFR) in the Eastern Arc Mountains of Tanzania. Specifically, the effects of climate change to peoples' livelihoods and the role of on-farm as an adaptation to the climate change effects were assessed. The role of existing on-farm trees as an adaptation to climate change effects was also investigated. Data was collected using household questionnaire surveys, Participatory Rural Appraisal (PRA), key informant interviews, tree stocking assessment on-farms and direct field observations. Temperature and rainfall data for the past 30 years were obtained from Mtibwa Sugar Company Weather Station. Results showed that the majority (92%) of the respondents were mainly engaged in farming and/or involved in various other economic activities such as livestock keeping, fishing, trading of forest products and petty business. CRiSTAL model results revealed that the main effects of climate change on peoples' livelihoods include decreased yield of agricultural crops, availability of fuelwood and increase in human diseases and natural disasters. Seventy percent of the respondents reported to rely on on-farm trees as an adaptation to climate change effects in the area. About 76% of the respondents in the area planted trees in their farms for this purpose. It was further learnt that people living around the reserve also used crop diversification, irrigation, fishing and petty business were as adaptation strategies to the. Results also indicate that adaptation to climate change is constrained by several factors such as lack of information and funds and shortage of water for irrigation in the study area. Findings of the study suggest the need for greater investment in local communities' education and improved institutional set up for climate change adaptation to improve their livelihoods.

Keywords: On-farm, trees, climate change adaptation, Mkingu Nature Forest Reserve.

INTRODUCTION

Climate change has been predicted to have serious effects on the ways in which humanity feeds itself (Fischer *et al.* 2005; Lobell *et al.* 2008) and is currently one of the greatest environmental challenges facing humankind (Lobell *et al.* 2008). Climate change is also arguably the greatest contemporary threat to forest ecosystems and biodiversity (Lobell *et al.* 2008). The projected impact of global climate change, particularly increasing temperatures, rainfall variability, frequency and severity of extreme events and increasing incidence of pests and diseases will likely affect the forestry and agriculture sectors (Howden *et al.* 2007; IPCC 2012; Lasco *et al.* 2014). Smallholder farmers in developing countries, in particular Sub-Saharan Africa largely depend on rainfed agriculture and forest resources, and therefore depend on complex interactions between local heat and hydrological feedbacks which dictate the temporality and spatiality of rainfall (Funk *et al.* 2008; Turpie and Visser 2013). Changing spatial and temporal patterns of temperature and precipitation regimes therefore exposes Africa's smallholder farmers and major agricultural production systems to tremendous climate risks, causing crop failure and affecting the livelihood and health of farmers (Hansen 2002; Meinke and Stone 2005; Meza *et al.* 2008; OECD 2008). For example, it is estimated that 30% of the world's rural population use trees which are present in 46% of all agricultural lands (FAO 2010) with 55% of people in sub-Saharan Africa living on land with at least 10% forest cover (Zomer *et al.* 2009). Incorporating trees and shrubs in food crop systems helps address food insecurity and increase CO_2 sequestration (FAO 2010) and reduce vulnerability of agricultural systems (Thorlakson 2011; Scherr *et al.* 2012). Poor countries in particular are the most vulnerable because of their high dependence on natural resources and their limited capacity to adapt to a changing climate (UNEP 2009). Smallholder farmers are therefore faced with the challenge of attaining food security while at the same time ensuring sustainability of their natural resource base, and struggling to cope with climate variability and change. As climate variability increases and related extreme weather events become more frequent and severe, there is a need to identify adaptation options to assist those most vulnerable to their impacts. On-farm tree planting is increasingly being recognized as a sustainable land use in multi-functional landscapes which enhances farmers' ability to adapt to climate change because of the multiple benefits it delivers including food provision, supplementary income and environmental services (Syampungani *et al.* 2010; Nzunda *et al.* 2013; Lasco *et al.* 2014; Soka and Ritchie 2016).

Perceiving climate variability is the first step in the process of adapting agriculture and forestry to climate change (Deressa *et al.* 2011). A better understanding of local communities' concerns and the manner in which they perceive climate change is crucial to designing effective policies for supporting successful adaptation in the agricultural and forestry sectors. Further, it is also important to have precise knowledge about the type and extent of adaptation strategies being taken up by farmers and need for further advances in existing adaptation set-ups. Hence, understanding how local communities perceive changes in climate and what factors shape their adaptive behaviour is useful for adaptation research (Mertz *et al.* 2009; Weber 2010). The choice of adaptation methods by farmers depends on various social, economic and environmental factors (Deressa 2007; Bryan *et al.* 2013). This knowledge will ultimately enhance the adaptation policies and their strength to tackle the challenges being imposed by climate change on local communities (Deressa *et al.* 2009). Adaptation will require the participation of multiple players from sectors such as research and policy, those in the agricultural extension services and private welfare organizations, as well as local communities (Bryan *et al.* 2013). Adaptation strategies tend to focus on technological, structural, social, and economic developments, and the linkages between biodiversity and adaptation are often overlooked (Campbell *et al.* 2008; Mertz *et al.* 2009). Biodiversity is linked to climate change adaptation and on-farm trees can play a role in societal adaptation. Studies have shown that planting trees on-farm can play an important role on adaptation to and mitigation of climate change effects (Thorlakson 2011; Scherr *et al.* 2012). Rural communities depend on-farm trees for livelihood, but the extent to which they adapt to climate change is not well known. There is existing information on how communities around MkNFR live with their livelihood assets and whether dependence on forest resources is high but currently access is limited. Communities around MkNFR have been planting trees on-farm but their role is not known as far as adaptation strategies to climate change are concerned.

The main objective of this study was to investigate the role of on-farm trees as a long-term and sustainable adaption strategy to climatic stresses (decrease and unpredictable rainfall, increased in temperature and drought) in communities living around MkNFR in the Eastern Arc Mountains of Tanzania. Specifically, the effects of climate change on the communities' livelihoods and the roles of existing on-farm trees as an adaptation to the climate change effects were investigated. The results are useful in raising awareness on how communities use on-farm trees as an adaptation strategy to climate change effects and could also influence tree resources utilization policies and conservation practices in Tanzania.

METHODOLOGY

Study area description

The study was conducted in 8 randomly selected villages namely Hembeti, Mkindo, Kigugu, Pemba, Maskati, and Gonja, Mafuta, Kwadoli in Mvomero district, Morogoro region bordering MkNFR (Figure 1). The reserve lies between latitude 6°01' and 6°13'S and longitude 37°26' and 37°37'E and covers 26,334 hectares (ha). The vegetation of MkNFR is of the Eastern Arc Mountains' forests type which is globally important for its biological values and nationally important for catchment values providing water to millions of Tanzanians (Lovett 1993; Burgess *et al.*, 2007). MkNFR has a high level of endemism for both plant and animal species with some of these species being threatened to extinction due to human activities.

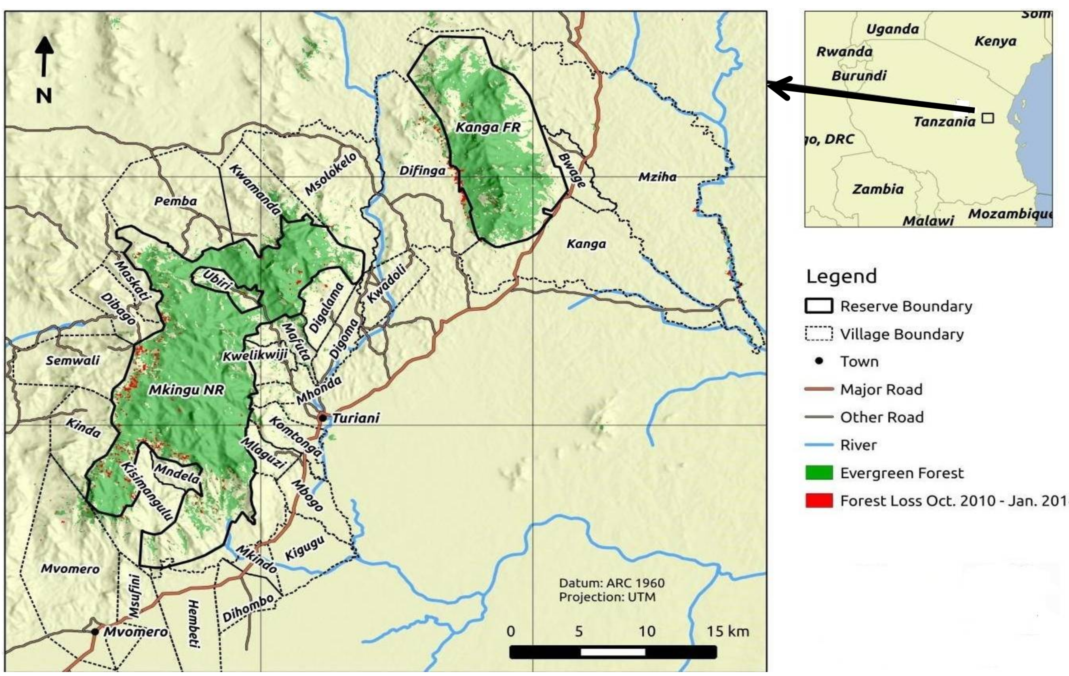

Figure 1: Map of MkNFR showing the surrounding villages (Adapted from MNRT 2009).

DATA COLLECTION

Primary data were collected using household questionnaire surveys, Participatory Rural Appraisal (PRA), key informant interviews, tree stocking assessment on-farms and direct field observations. Climatic data (annual rainfall and monthly temperature) and natural calamities for the last 30 years that occurred in the study area were obtained from Mtibwa Sugar Company Weather Station.

Household questinnaire surveys

A household was the sampling unit in this survey. A semi-structured questionnaire with both closed and open-ended questions was used to collect household data. The questionnaire was designed to permit acquisition of both quantitative and qualitative information. The questions were designed to focus on key issues on socio-economic variables such as gender, household size, occupation, household income, age, and education level of household head and agricultural production. The key issues addressed during data collection were on-farm trees in the area, potential climate change hazards, coping and adaptation strategies found in the area. Also, data were collected on perceived effects of climate change on local community's livelihoods, vulnerability and adaptation strategies. A pilot study of 10 households was conducted prior to the questionnaire survey to check reliability and validity of the information. This was essential in order to take into account ambiguity of some of the questions in the questionnaire (Mettrick 1993). A total of 120 households around MkNFR was selected for interviews. According to Bailey (1994), regardless of the population size, a sample of 30 cases is the bare minimum for valid statistical data analysis.

Participatory Rural Appraisal

PRA is an exploratory method that aims at having a dialogue with stakeholders and getting information from them through participatory communication and analytical method (Duangsa 1996). The participatory tools and techniques for assessing climate change impacts and exploring adaptation options used by Regmi *et al.* (2010) were modified and adopted for use during the study. The tools were resource mapping to map local climatic hazards; matrix scoring; climatic hazard trend analysis to gain insight into past hazards; climatic hazard ranking to compare and contrast the impact of major climatic hazards on the social group; vulnerability assessment; adaptation strategies to assess the effectiveness of the current adaptation strategies.

Focused group discussions were employed to encourage collective response of the link between climate change and variability and the livelihood. The focused group discussions comprised of 10-15 men and women aged more than 30 years with knowledge and experience on the climate change issues. This assisted to gather information on the link between on-farm trees and livelihood, the impact of climate change, current hazards and coping strategies. Also, livelihood context information especially how resources are affected by hazard and coping strategies was obtained by focus group discussions. This social science tool helped to triangulate the information collected through semi-structured questionnaires.

Key informant interviews

While group meetings can provide details on the broad context for local circumstances and practices, there are frequently particular individuals who for a number of reasons have acquired significant knowledge about specific issues (Katani 1999). These individuals come from a variety of segments of society including farmers, elders and priests. What sets them apart as key informants is that they are recognized by others in their community as being particularly knowledgeable about the area. For the purposes of the study, Forest Officers, Village Natural Resource Committees (VNRC), village leaders and knowledgeable elders in the villages were interviewed.

Assessment of stocking of trees on-farms
Four1000 m long transect-lines spaced 500 m apart that originated from the edge of the reserve were laid in each village. Five plots located at 200 m apart were established along each transect line. Random sampling was employed where by square plots measuring 20 m x 20 m were established in different farms in the 8 villages surrounding MkNFR. Each of the sample plots laid in the field was geo-referenced using a GPS for future reassessments where needed. Tree stocking of the farm in terms of frequency and abundance from stem counts, diameter at breast height (DBH) of all trees ≥ 5 cm, percent cover for each species and plant species composition were assessed.

DATA ANALYSIS

Data collected through structured and semi structured questionnaire were analysed using Statistical Package for Social Sciences (SPSS) to obtain descriptive statistics such as percentages of responses, frequencies, and means, and the results were used for construction of tables. Data collected through PRA were analysed with the help of communities in the study area and the results communicated back to them for verification. Content and structural functional analyses were used to analyse qualitative data and information. The components of verbal discussion were analysed in details with the help of content analysis method. The recorded conversations with respondents were broken down into smallest meaningful units of information to ascertain values and attitudes of the respondents. The Community-based Risk Screening Tool for Adaptation and Livelihoods (CRiSTAL 3.0) was used to synthesize information from focus group discussions on the link between climate change and communities' livelihoods. This provides a holistic picture of the current climate hazards and impacts on local livelihoods and ascertains values and attitude of respondents. Data were analysed qualitatively and quantitatively to ensure their consistency and a better understanding of the role of on-farm trees to communities' livelihoods under current climate change and variability. The tree stocking data were analyzed for basal area (m^2/ha). The stand basal area (m^2/ha) of on-farm trees was obtained by adding the basal areas all of the trees in the study site and divided by the area of land in which the trees were measured. In this study, basal area represents stocking. Stocking can be defined as quantitative measure of the area occupied by trees, usually measured in terms of basal area per hectare, relative to an optimum or desired level of density (Hédl *et al.* 2009). Microsoft Excel software tool was used to analyze meteorological data to generate the climatic change trends (annual means of temperature, and total annual rainfall) of the study site from 1983 to 2013.

RESULTS

Socio-economic characteristics of the respondents
About 41% of the respondents were from female-headed households while the remaining 59% were from male headed households. It was found that the average family size of the respondents was 6 people. In terms of educational levels, about 62% of the respondents had received primary education, 27% of the respondents had no formal education and while only 12% had attained secondary education. It was revealed that 83% of the respondents had lived in the area for between 18 and 60 years and only 17% of them had lived in the area for more than 60 years. The age of the respondents was categorized into three groups namely 18 - 30, 30 - 60 and greater than 60. It was done in order to obtain

different views on climate change and variability from different age groups. The majority (78%) of the respondents were aged between 30 and 60 years old. Only 8.2% of the respondents were less than 30 years while 13.8% were older than 60 years old. The majority (84%) of the respondents interviewed were married, 13% were widowed, 3% were single and only 2% were divorced. Results show that the majority (92%) of the respondents were mainly engaged in farming and/or involved in various economic activities such as livestock keeping, fishing, trading of forest products as well as conducting petty business around the reserve.

Changes in climate around MkNFR

Changes in rainfall patterns

The trend analysis of the annual rainfall from 1983 to 2013 shows fluctuations of rainfall patterns with the highest amount of rainfall recorded in 1997 and the lowest amount in 2013 (Figure 2). The mean and standard deviation of rainfall data were 1193.46 mm and 245.02 mm respectively (Table.1). The coefficient was -5.09 mm/year and implies that there is a decrease in the amount rainfall over time for the past 30 years. Also, the value of coefficient determination was 0.035 which shows that there is positive relationship between amount of rainfall and time in the study area. The majority (94%) of the respondents agreed that there have been changes in the rainfall patterns over 30 years.

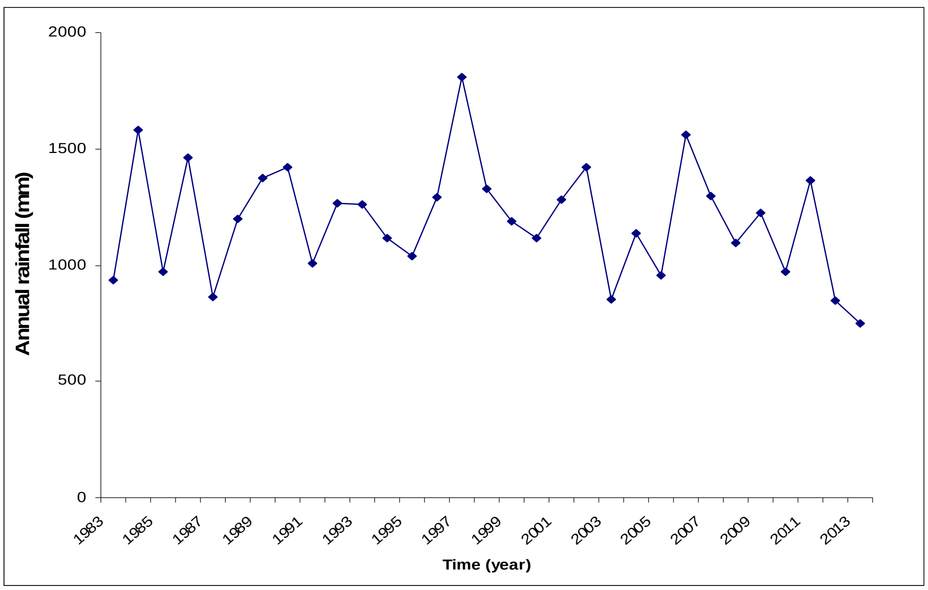

Figure 2: Annual rainfall patterns from 1983 to 2013 around MkNFR

Changes in temperature

The changes in temperature patterns from 1983 to 2013 showed an increasing trend in the level of mean monthly temperatures with the highest (32.0^{o}C) recorded in 2010 and minimum (28.69^{o}C) recorded in 1986 (Figure 3). The results show that the mean value of temperature and its standard deviation over the period were 30.92^{o}C and 0.73^{o}C respectively. The trend coefficient was 0.049 ^{o}C/year that implies that an increase in temperature over time for the past 30 years. The coefficient of determination was 0.365 and implies that there is an increase in temperature over time in the study area. Majority of the respondents agreed that there have been changes in the temperature in the area.

About 89% of them reported that there has been an increase in temperature for the more than 30 years ago around MkNFR.

Perceptions on effects of climate change on peoples' livelihoods

Agriculture scored the highest and ranked number one economic activity/livelihood resource affected by climate change. Forty three percent of the respondents agreed climate change has caused negative impacts on agricultural activities and peoples' livelihoods. Results from CRISTAL Model also revealed that agriculture was the most livelihood resources affected by climate change. Matrix scoring results showed that crop productivity was ranked number one being affected by climate change and variability, followed by health of the people living in the area.

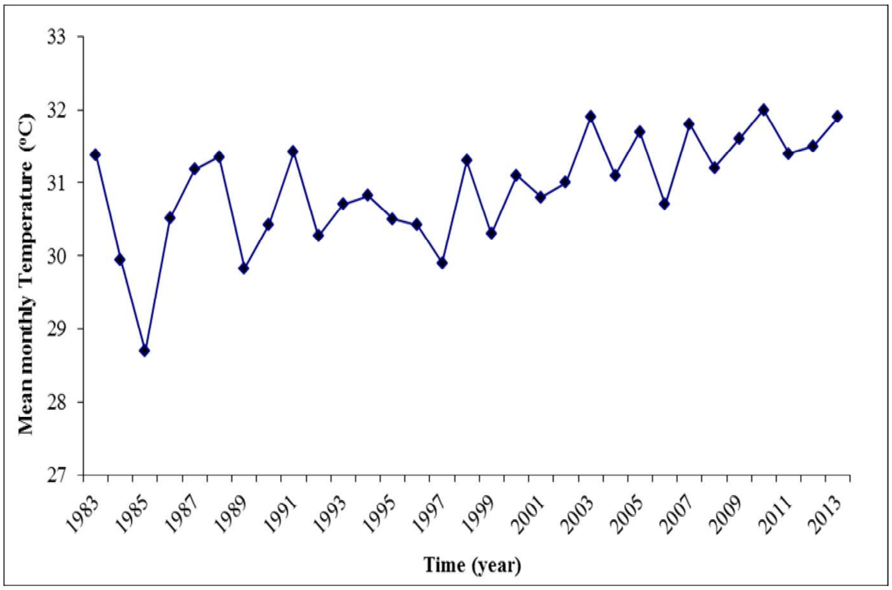

Figure 3: Mean monthly temperature from 1983 to 2013 around MkNFR

Climate change is believed by local communities to exacerbate human and livestock diseases by changing environmental factors that lead to the growth and development of insects transmitting diseases around MkNFR. CRISTAL Model results show that increase in temperature resulted in an increase in plant and human diseases (Table 1). It was revealed that about 40% of the respondents agreed there has been an increase in human diseases mainly malaria, measles, cough, stomachache and cholera. It was reported that some diseases have become pandemic in the area and are associated with climate change and variability. For example, increased in mosquito populations resulted in the increase in malaria incidences compared to the previous years. About 60% of the respondents reported to suffer from malaria at least twice in a year.

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Table 1: Responses on climate change and variability effects to livelihoods

Response	% Response (N)
Decreased agricultural crops	43 (52)
Increased human diseases (malaria, measles and cholera)	40 (48)
Increased natural disasters	14 (16)
Decreased in firewood	3 (4)
Total	**100 (120)**

Note: Figure in the brackets present frequencies of responses and outside brackets present percentages of respondents.

Natural disaster incidences around MkNFR

It was learned that floods, drought and severe storms were the mainly natural disasters occurred in the study area. PRA results show that there has been an increase in floods and drought incidences around MkNFR. About 46% of respondents agreed major floods occurred twice for the past 30 years. Sixty two percent of the respondents agreed that severe drought has occurred more than three times in the area for the past 30 years. The results generated by the CRISTAL model demonstrated that people living around MkNFR have witnessed severe storms linked to changes in climate in the area. During PRA, the respondents recalled the heavy rains and floods that occurred in 1997 and 2007 in their area. The rains caused floods which resulted in serious damage to agricultural crops, roads and houses in the area.

Domestic energy

It was revealed that firewood was the main source of cooking energy to the communities living around MkNFR. About 76% of the respondents admitted to use firewood as the main source of cooking energy in their households. The majority (85.5%) of the respondents agreed that the availability of firewood has been decreasing over time. The decrease in sources of energy may not only be caused by climate change but also by human activities due to forest deforestation and degradation.

On-farm trees as an adaptation strategy to cope with climate change and variability

The results showed that respondents around MkNFR depend on-farm trees as a major source of food and vitamin, as source of household incomes and as strategy for soil and water conservation.

On-farm trees as source of food and vitamin

The results show that about 76% of the respondents admitted to have planted trees on-farm and agreed to use on-farm trees resources such as fruits and vegetables as climate change effect adaptation strategy. *Citrus sinensis, Citrus limon* and *Mangifera indica* were the major fruits planted and used by the respondents. Fruits and vegetable are important in improving vitamin A status. It was also observed that farmers integrate a wide range of livestock with on-farm tree recourses in order to reduce the vulnerability to climate change hazards in the area. Results show that livestock kept included cows, sheep, goat, rabbits and chickens. They believed that the integration of livestock with on-farm trees plays a vital role in improving their household food security.

On-farm trees as source of household income

It was revealed that 57.8% % of the respondents interviewed admitted to use and plant on-farm trees to increase their household income as a strategy to climate change effects in the area. Income from on-farm tree products could be generated in a number of ways. Households may sell products in their farm including fruits, vegetables, animal products and other valuable materials such as wood for construction or fuelwood. It was revealed that 64% of the respondents consume and sale on-farm tree products as a climate change and variability coping strategy. They use on-farm tree products such as fruits, poles, woodfuel and medicinal plants. On-farm tree products can either be sold in Turiani market or Morogoro town. It was recorded that most of the tree species planted included *Tectona grandis*, *Cedrela odorata*, *Senna siamea*, *Khaya anthotheca*, *Citrus sinensis*, *Citrus limon*, *Mangifera indica* and *Pterocupos angoresis*.

On-farm trees as strategy for soil and water conservation

In this study, local people reported to be dependent on-farm trees as a strategy for soil and water conservation through provision of permanent cover. The results revealed that 42.9% of the respondents interviewed agreed to have planted trees and herbaceous plants on-farm as strategy for conservation of water and soil.

On-farm trees as strategy for combating climate change effects

Seventy percent of the respondents interviewed agreed to rely on on-farm tree products as strategy for combating climate change effects around MkNFR (Table 2). About 94% of the respondents reported that on-farm tree planting was the most effective coping strategy in combating climate change effects in the area.It was observed that within the homesteads, people usually have home gardens and plant various timber tree species, horticultural species and seasonal vegetables to meet their own needs and sometimes to sale for additional cash income. Furthermore, it was learned that about of the respondents (76%) adapted diversification of the agricultural crops as a preferred copping strategy to the climate change and variability. The main crops intercropped in the growing season included maize, cassava, yams, beans, bananas, peas and sunflower. In addition, 68% of the respondents admitted to delay sowing seeds due to changes in the rainfall patterns.

Table 2: Response on on-farm economic activities as coping strategies to climate change

Adaptation strategy	% Response (n)
On-farm tree planting	70 (84)
Diversification of the agricultural crops	76 (91)
Irrigation and delay sowing seeds	68 (82)
Timber selling from own farm	24 (29)
Use of On-farm NTFPs	43 (52)
Livestock keeping	47 (56)

Note: Figure in the brackets present frequencies of responses and outside brackets present percentages of respondents

Relative frequency, basal area and diameter distribution on-farm around MkNFR

A total of 67 different tree species were identified to be planted on-farm. The two tree species, *Tectona grandis* and *Khaya anthotheca* were more abundant than others and the tree species accounted for 57.5% of the all trees on-farm (Table 3). Furthermore, the most abundant species in all three DBH classes were *Tectona grandis* and *Khaya anthotheca* species. As expected, *Tectona grandis* and *Khaya anthotheca* had the highest basal areas of 5.8035 and 1.5181 m^2/ha respectively. Other tree species had the basal area less than 1 m^2/ha. A reverse J-shape curve of the number of trees over DBH was noted around MkNFR (Figure 4). Also, ample regeneration through seedlings and re-sprouting through stem coppices and root suckers was observed on-farms.

Table 3: Basal area and relative frequency of identified tree species on-farm around MkNFR

Botanical name	Vernacular name	Relative frequency (%)	Basal Area (m^2/ha)
Acacia drepanolobium	Vuvula	0.105	0.0071
Acacia mellifera	Mgunga	0.419	0.0442
Albizia gummifera	Mkenge	0.052	0.0133
Albizia versicolor	Mkingu	0.367	0.0233
Annona chrysophylla	Mtopetope	0.052	0.004
Annona squamosa	Mstafeli	0.21	0.0158
Araucaria cunnighamii	Mvedera nyani	0.21	0.0164
Artocarpus heterophyllus	Mfenesi	1.834	0.0532
Arundinaria alpina	Mianzi	0.314	0.0028
Azadirachta indica	Mwarobaini	1.785	0.0107
Blighia unijugata	Mkalanga	0.58	0.3606
Brachystegia boehmii	Myombo	0.21	0.0146
Brachystegia bussei	Msani	0.63	0.0113
Carica papaya	Mpapai	0.157	0.0102
Cederela odorata	Msederela	3.2	0.1779
Celtis sp.	Mkoma chuma	0.157	0.011
Cinnamomum zeilanicum	Mdalasini	0.21	0.0133
Citrus limon	Mlimao	0.052	0.0038
Citrus sinensis	Mchugwa	1.99	0.0584
Citrus tangerines	Mchenza	2.78	0.1411
Cocos nucifera	Mnazi	2.411	0.0518
Combretum molle	Mlama	0.367	0.0028
Combretum zeyheri	Mlama mweupe	0.052	0.0073
Commiphora eminii	Mlemela	0.105	0.007
Deinbollia borbonica	Mmoyomoyo	0.052	0.0036
Deinbollia sp.	Mbwakabwaka	0.052	0.0034
Diospyros fischeri	Mdaa	0.052	0.0063
Euterpe oleracea	Mchikichi	0.472	0.0064
Ficus stuhlmannii	Mkuyu	1.1	0.0351
Flacourtia indica	Mchongoma	1.68	0.2151
Flueggea virosa	Mkwamba	0.157	0.0097
Garcinia huillensis	Mpilipili	0.157	0.0107
Grevilia robusta	Grevelia	0.58	0.0095
Grewia bicolor	Mkole	0.052	0.0027
Holarrhena pubescens	Mmelemele	0.105	0.0091
Hyphaene compressa	Mkamakungu	0.419	0.005
Jacaranda mimosifolia	Mkrisimasi	0.052	0.0046
Khaya anthotheca	Mkangazi	18.344	1.5181
Leucina leucocephala	Mlucina	2.254	0.1305
Lonchocarpus capassa	Mfumbili	0.419	0.005
Lonchocarpus capassa	Mfumbili	0.472	0.0064

Manilkara sulcata	Msezi	0.157	0.0112
Markhamia acuminata	Mtalawanda	0.21	0.0141
Mengifera indica	Embe	4.3	0.5418
Milicia excelsa	Mtunguru	0.052	0.0032
Milicia excelsa	Mvule dume	0.21	0.0149
Millettia lasiantha	Mhafe	0.21	0.0143
Opilia celtidifolia	Mfulu	0.943	0.0875
Parinari excelsa	Mmula	0.105	0.0093
Persea americana	Mparachichi	0.52	0.0375
Pseudolachnostylis maprouneifolia	Msolo	0.63	0.0066
Psidium guajava	Mpera	1.42	0.2079
Pterocarpus angolensis	Mninga	0.262	0.0025
Ricinodendron heudelotii	Mtene	0.052	0.0061
Sclerocarya birrea	Mng'ong'o	0.262	0.0221
Scorodophloeus fischeri	Mhande	0.157	0.0099
Senna siamea	Mjohoro	0.367	0.0166
Sterculia appendiculata	Mgude	0.105	0.009
Sterculia quinqueloba	Mhembeti	0.157	0.0126
Stereospermum kanthianum	Mkomanguku	0.21	0.0183
Syzygium cordatum	Mzambarau	0.052	0.0045
Tamarindus indica	Mkwaju	0.052	0.0058
Tectona grandis	Mtiki	39.203	5.8035
Terminalia sambesiaca	Mpululu	0.052	0.0043
Terminalia torulosa	Mkoko	0.052	0.0056
Theobroma cacao	Cocoa	5.398	0.5383
Vitex doniana	Mfuru	0.21	0.0145

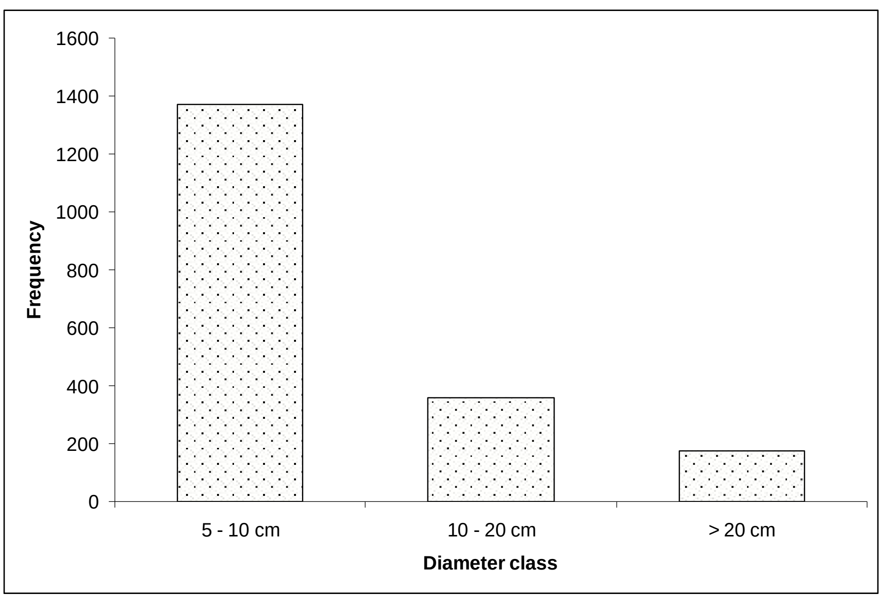

Figure 4: Diameter distribution of on-farm trees around MkNFR.

DISCUSSION

Characteristics of respondents

There was almost equal representation of both male and female-headed households. This has given outlook on how both headed households perceived changes in climate change and adaptation strategies. The average family size of the respondents was 6 people was noted around MkNFR. Household size has an important socio-economic implication in household`s ability to improve its livelihood. In this study, majority of the respondents had received primary education. Educated people stand a good chance of adopting new technologies and adaptation strategies options in coping with climate change. Education is necessary to enable someone to easily adopt and transform with new technologies in coping with climate change (Vignola *et al.* 2015; Ziervogel *et al.* 2005). The age, education attainment, income and family size have been reported to positively related to adoption of technologies (Farid *et al.* 2015). From the existing literatures it is evident that adoption of technologies in farming practices is affected by certain factors (Ziervogel *et al.* 2005; Hansen *et al.* 2007; Salehin *et al.* 2009). Majority of the respondents had lived around MkNFR between 18 and 60 years. This implies that the respondents have accumulated a lot of experience and knowledge on availability, values and role of on-farm trees, climate change and variability in the study area. It was clear that increase in years of staying in the study area increased knowledge on climate change and variability. Furthermore, the majority of the respondents interviewed around MkNFR were married. Understanding the distribution of marital status of respondent is important for assessing management and utilization of forest resources (de Sherbinin *et al.* 2008). It was noted all the respondents were mainly engaged in farming and/or involved in various economic activities around the reserve. This implied that local people were involved in various activities simply because they are of great value to them in terms of food, health as well as cash.

Changes in climate around MkNFR

The people's perceptions were in line with the climatic data records. Majority of the respondents reported that there have been changes in the rainfall patterns over 30 years. They noticed a change not only in the total amount of rainfall but also in the timing of the rains; with rains coming either earlier or later than expected. The observed fluctuations of rainfall patterns suggest there have been variations in the amount of rainfall over time for the period under consideration. For example, villages around MkNFR experienced El-Ninos in 1997. The findings are similar to Msalilwa *et al.* (2013) who reported that 1997 had the highest amount of rainfall in Kilolo District. Fluctuations of rainfall patterns may be continued, which might affect agricultural productivity. This affects people's livelihood since 89% of the community living in the area depends on agricultural activities as livelihood strategy. The observed changes in temperature patterns suggest an increasing trend in the level of mean monthly temperatures for the period under consideration. Majority of the respondents agreed that there have been changes in the temperature in the area. Changes in temperatures was reported to have caused poor crop yield, spread of diseases and pest, increase in evapotranspiration and reduces productivity of the farms resulted in low income.

Perceptions on effects of climate change on peoples' livelihoods

Climate change has been reported to affect agriculture, with effects unevenly distributed across the world and has increased the risk of food insecurity for some vulnerable groups (Maddison *et al.* 2007; Kang *et al.* 2009; Athula and Scarborough 2011). Climate change introduces uncertainties in the livelihoods of communities having higher dependence on weather and climate (Al-Hassan and Poulton 2009; Athula and Scarborough, 2011). It is becoming a threat towards world community through increasing temperatures, reduced precipitation, frequent droughts and scarcity of water (Adger *et al.* 2003; IPCC 2007; Msalilwa *et al.* 2013). The basic elements of food production such as soil, water and biodiversity are negatively affected by climate change (FAO 2009). Local communities around MkNFR have been modifying their farming practices to better adapt to the changing climate. But the traditional coping mechanisms are not sufficient for dealing with medium to long-term impacts of climate change (FAO 2009). In our study, it was revealed that climate change has caused negative impacts on agricultural activities and human peoples' livelihoods. Similarly, Lyimo and Kangalawe (2010) reported that about 70% of the households interviewed in Shinyanga Region indicated that crop production was on a decline trend due to climate change. The overall effect of climate change on agriculture especially in the tropics has been highly negative (Maddison *et al.* 2007). Rising temperatures and changes in rainfall patterns have direct effects on crop yields, as well as indirect effects through changes in irrigation water availability. These results to low crop yield and hence low income since most of the respondents depend on agricultural activities. Low crop yield may also associate with non-climatic factors such as decline of soil fertility, pest and diseases and inadequate extension services around MkNFR. Climate change is believed to exacerbate human and livestock diseases by changing environmental factors that lead to the growth and development of insects transmitting diseases around MkNFR. Common human diseases included malaria, measles, cough, stomachache and cholera were reported around MkNFR. Interestingly, these diseases have become pandemic, there incidences are on the rise in the area and are associated with climate change and variability. Moreover, increased in mosquito populations resulted in the increase in malaria incidences compared to the previous years. Local people around MkNFR have witnessed several natural disasters including floods, drought and severe storm. They believed that these natural disasters are linked to changes in climate in the area. The increase in natural disasters incidences may not only be caused by climate change but also by human activities due to forest deforestation and degradation. It was further revealed that local people around MkNFR have been planting trees on-farm and an adaptation strategy to climate change.

On-farm trees as an adaptation strategy to cope with climate change and variability

In this study, it was learned that local people around MkNFR plant trees on-farm for several reasons including a major source of food and vitamin, as source of household incomes and as strategy for soil and water conservation. They also integrate a wide range of livestock with on-farm tree recourses in order to reduce the vulnerability to climate change hazards. On-farm tree products could be consumed by the household or sold in the nearby markets. Mitchell and Hanstad (2004) observed that income from agroforestry significantly improves the family financial status in many parts of the world; justifying the revenue generating potential of agroforestry. Equally, Marsh (1998) noted that economic returns to land and labour are often higher for agroforestry practices than any other systems of agriculture.

Planting different tree species diversity on-farm has been reported to be a strategy for soil and water conservation (Ruiz-Jaen and Potvin, 2010; Wang *et al.* 2012; Sarvade *et al.* 2016). Similarly, local people around

MkNFR agreed to have planted trees and herbaceous plants on-farm as strategy for conservation of water and soil. According to FAO (2000), on-farm trees promote low tillage and maintenance of permanent soil cover that can increase soil organic matter and reduce impacts from flooding, erosion, drought, heavy rain and winds. In this study, it was noted that tree are also planted in homesteads as strategy for combating climate change hazards. This implies that local people around MkNFR have started relying on on-farm trees as a coping strategy. Undoubtedly, human influences have implications for the present role of agricultural lands and forests in global carbon cycles and in future carbon sequestration. In order to mitigate climate change, more carbon should be sequestered in ecosystems and strategies for an adapted forest management are sought (Dixon *et al.* 1994). In this study, diversification of the agricultural crops was revealed as a preferred copping strategy to the climate change and variability. A study by Blench (2003) found that farmerjs minimize or spread risks by managing a mix of crops, crop varieties and sites; staggering the sowing/planting of crops; and adjusting land and crop management to suit the prevailing conditions. Furthermore, local people have adopted delayed sowing of seeds due to changes in the rainfall patterns. Similarly, Akponikpe *et al.* (2010) reported that farmers change sowing dates for similar reason in West Africa.

Tree species relative frequency and diameter distribution on-farm around MkNFR

On-farm tree planting seem to have increased tree species diversity around MkNFR. The two timber tree species (*Tectona grandis* and *Khaya anthotheca*) were the most abundant on-farm around MkNFR. In regards to the reproductive capacity of on-farms near MkNFR, the diameter distribution follows a reversed J-shape meaning the number of lower diameter class (young) trees is higher, an indication of adequate recruitment. A reverse J-shape describes a curve of number of trees over DBH that is steeply and steadily declining (Rubin *et al.* 2006).

CONCLUSIONS AND RECOMMENDATIONS

Majority of local people depend on socio-economic activities mainly agricultural production, livestock production, and fishing, selling forest products and petty business to sustain their day to day life around MkNFR. Diversification to on-farm economic activities was important in enhancing household adaptive capacity. Climatic data are in line with local peoples' perceptions. Agrcultural activities were the most livelihoods' resorce affected and vulnerable to climate change and variability. The main effects of climate change to peoples' livelihoods include decrease yield of agricultural crops, increase in human diseases and increase in natural disasters and reduction in fuelwood for cooking. Children and women are most vulnerable groups by climate change. It was clear that most of the respondents adapted more than one adaptation strategy to climate change and variability. Majority of the respondents relied on on-farm trees as a strategy for combating climate change hazards in the area. Respondents planted trees in their farms as a strategy to climate change effects in their area. Crop diversification, irrigation, fishing and conducting petty business were among the adaptation strategies to the people living around the reserve. Adaptation to climate change was constrained by several factors including lack of information, lack of funds and shortage of irrigation water in the study area. There is a need for greater investment in local communities' education and improved institutional set up for climate change adaptation to improve peoples' livelihoods.

This study recommended the following measures:

(i) Reliable climate and weather information from the nearby meteorological stations should be conveyed to local people through public media to assist them in their agricultural activities.

(ii) The government should increase awareness on the effects of climate change and variability issues as well as improve the existing coping strategies to enhance the adaptive capacity and in turn improve peoples' livelihoods.

(iii) Government policies should also facilitate local communities' access to affordable credit with low interest to increase their ability and flexibility to change production strategies in response to the forecasted climate and improve on-farm income-earning opportunities.

(iv) Furthermore, establishment of tree nurseries and provision of tree seedlings to the local communities around MkNFR should be encouraged to supply the community with required wood source.

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