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Cyperus papyrus in Lake Victoria: Genetic Information, Utilisation and Resource Sustainability

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Abstract

Many wetlands in the Lake Victoria basin are dominated by *Cyperus papyrus*, which are very productive and, therefore, have an important role both ecologically and socially. The increasing harvesting pressure of papyrus threatens its future. Thus, a conservation approach was employed to determine the intensity of the pressure and threat to the papyrus diversity at clonal level. Eight microsatellite loci were used for analysing the clonal diversity and genetic diversity of *Cyperus papyrus* in 6 swamps of Mwanza bay (Tanzania) and 5 swamps of Nyanza bay (Kenya). From 304 individuals, we observed a total of 49 alleles in Mwanza bay and 44 alleles in Nyanza bay, a high clonal diversity (R = 0.64 to 1 Mwanza bay and R=0.70 to 1 in Nyanza bay), and a high genetic diversity (HE) with an average of 0.558 and 0.493 for Mwanza and Nyanza bay, respectively. The analysis of molecular variance showed that most of the allelic variances were within individuals. This resulted in a moderate differentiation (FST, 0.126 and Nm, 1.7) from all studied population in Lake Victoria. Gene flow was high between populations within each bay of the Lake (Nm > 4). The observed disturbance in the swamps showed no effects on any of the papyrus diversity variables. The clonal diversity (R) was even higher in the disturbed swamps than in pristine ones, with values ranging from 0.78 to 1 for disturbed, and 0.64 to 1 for pristine swamps. This explains that, although it is a clonal plant, papyrus maintains sexual reproduction and successful seed dispersal, making them resilient to even strong environmental and anthropogenic disturbance.

Keywords: *Cyperus papyrus*, *macrophytes, resilience, disturbed, harvesting, diverse*

Introduction

Wetlands are described as intermediate areas of neither fully terrestrial nor fully aquatic. They are the most productive ecosystems with a wide range of natural functions, which are valuable to humanity. Unfortunately, they are the most threatened due to their vulnerability and attractiveness to development (Hollis et al., 1988).

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Since wetlands are characterised by vegetation type, water and soil conditions, influences such as presence or absence of grazing biotic groups—for example, fish, macro invertebrates and amphibians—still they are important for planetary and human health. They provide vital ecosystem services, for example, water purification, nutrient cycling and large quantities of carbon storage, flood reduction, recharging ground water supplies and protection of the shoreline (Ryan et al., 2011). Mitsch et al. (2000) described wetlands as multiple value systems with public luxuries, valuable products, and wetland values that are potentially long lasting. However, unsustainable and resource depleting human practices of agriculture and industrial or commercial activities in wetlands render the loss of wetlands, and the loss of these functions and values is often irreversible.

Tanzania has a vast area of wetlands (Bakobi, 2003). The Lake Victoria basin, the second largest surface fresh water body on earth with an area of 68,800km^2 (Newell, 1960), has about 10,235.17km^2 of wetlands shared by three East African countries (Tanzania - 49%, Uganda - 45% and Kenya -6%). About 80% of these wetlands is papyrus dominated (Kansiime et al., 1999).

Papyrus reproduces both sexually by seed formation from the umbels and asexually by vegetative reproduction through the rhizome. Boar et al., (2006) explained the germination of papyrus seeds in twelve days and their inability to germinate in standing water.

As they create a buffer zone between terrestrial and aquatic ecosystems, papyrus swamps play a great hydrological, ecological and economic role in Central tropical and West African wetlands (Gaudet, 1980). The ongoing unwise utilization of wetlands and wetland resources in the Lake Victoria basin hampers their persistence. Such activities as agriculture, pollution, wetland drainage and settlement expansion have converted wetlands to settlement areas in Mwanza, Bukoba, Musoma, Kahama and Bunda all in Tanzania (Kassenga, 1997). Burning of papyrus wetlands in Lake Victoria basin contribute 5.2×10^7 tons of carbon dioxide in the atmosphere. In general, the future of the lake and wellbeing of the people living around the lake depends on the status of the papyrus wetlands (Kiwango, 2007).

The utilization of papyrus for socio-economic purposes is diverse, from the papyrus wetland to the plant itself. Terer et al., (2012) documented the utilization of papyrus swamps for farming and livestock grazing; and papyrus for making mats, fodder, roofing materials, fishing activities and for fuel (Fig.1).

Fig. 1: ***Some of papyrus uses. Top: Houses and fence made of papyrus stems; Bottom: Cattle grazing on papyrus swamp (photo by Lusasi J)***

Most of the riparian communities use papyrus as a resource or raw material for developmental activities. As mentioned earlier, the current unsustainable harvesting of papyrus in freshwater wetlands threatens the future of the resource and wetlands at large (Terer et al., 2012). The determination of the effects of disturbance in papyrus swamps is a good attempt to sustainably conserve this resource. Sustainable utilisation of papyrus will eventually lead to maintaining the wetland ecosystem services.

The information on papyrus in Tanzania and Kenya is limited (Kiwango & Wolanski, 2008). There is no published information on the population genetic status. Due to the lack of enough scientific information on

sustainable utilisation of *Cyperus papyrus* and its clonal status, it is hard also to plan for its conservation. The loss of papyrus due to unsustainable utilisation will lead to loss of genetic resource.

While the loss of connectivity between landscapes—i.e., habitat fragmentation—leads to loss of natural communities and biological diversity, the loss of population leads to a loss of unique genetic information, genetic diversity and, eventually, decline of total biological diversity in an area. This kind of loss is normally not recoverable (Ferar, 2002). Usually, small populations have low genetic diversity and are genetically threatened. Studies on the genetics of aquatic plants are very wide as shown by a body of literature (Ouborg et al., 2006), which documented low and high genetic variation among aquatic plants.

Using microsatellite marker, Terer (2011) observed high genetic diversity for *Cyperus papyrus* due to high sexual reproduction and seed recruitment. Although Zielder (1994) observed high level of genetic variation and structure among *Phragmites australis* population as a result of sexual reproduction using RFLP marker, Pellegrin and Hauber (1999) observed the lack of genetic variation among populations due to insignificant sexual reproduction in the same species.

Plants in *Cyperaceae* family have high clonal diversity (Ohsako, 2010); with moderate level of genetic diversity and less inbreeding due to outcrossing among dioecious plants of *Carex kobomugi*.

This study focused on three main objectives, namely to:

1. Determine the genotypic richness/clonal diversity, genetic diversity and structure of *Cyperus papyrus* in selected wetlands of Lake Victoria.
2. Determine the genotypic richness and genetic diversity between disturb and pristine papyrus swamps of Lake Victoria.
3. Assess the community local ecological knowledge (LEK) on utilisation, perception of sustainability and management practice of papyrus swamps in Tanzania.

Materials and Methods

In Tanzania, the study was conducted in Kamanga, Mwanza bay, namely in Kabagombe (KBTZ), Uswahilini (USTZ), Mabatini (MATZ), Chigoto (CHGTZ), Chamagati (CHATZ), and Luchelele (LUTZ) (Fig. 2).

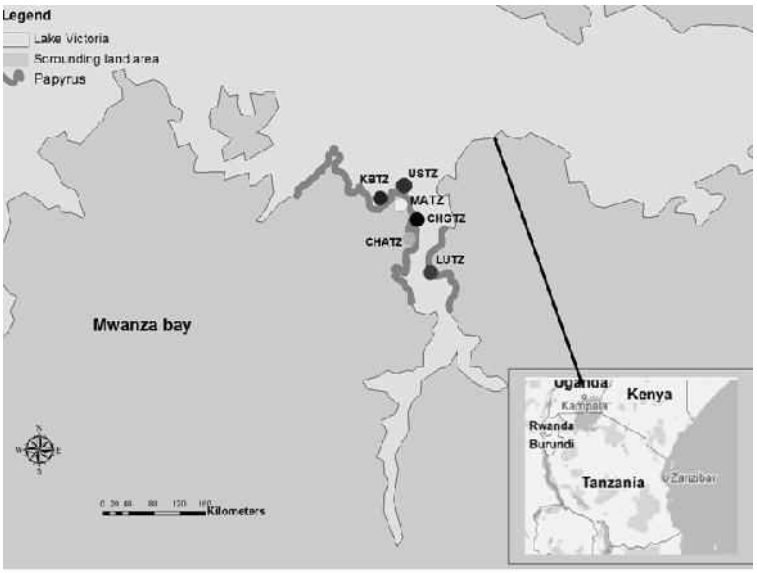


Fig. 2: ***Map of Tanzania showing the Mwanza bay sampling sites***

Other samples were collected in five swamps of Nyanza bay, Kenya: Sondu (LVSO), Nyando (LVNY), Kibosi (LVKI), Kenya Marine Fisheries Institute (LVKK) and Usengi (LVUS) (Fig. 3) and are described in Terer et al. (2011).

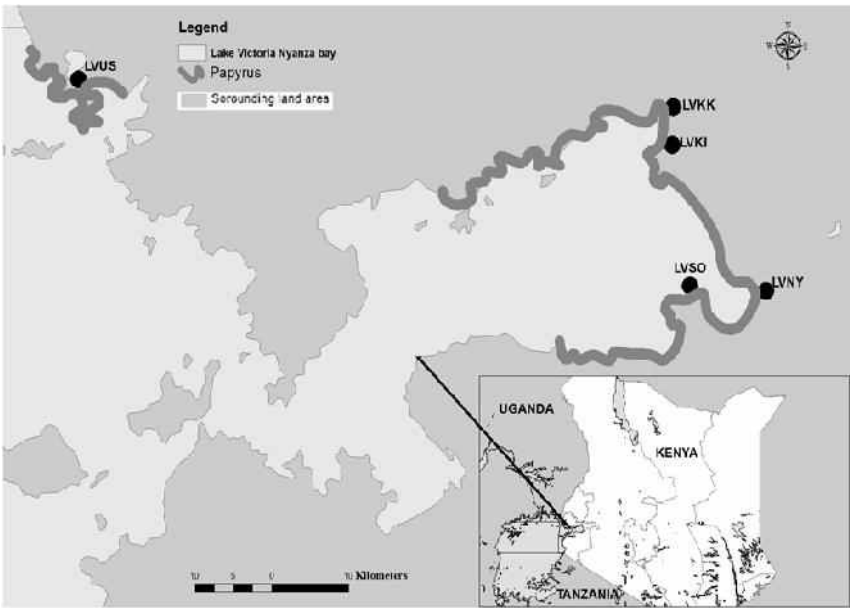


Fig. 3: ***Map of Kenya showing the sampling sites in Nyanza bay***

Sampling Design
At each site, 30 stems of mature plants were randomly selected at a distance of >3m from each other. From the mature stem, about 3cm of the stem was peeled, dried and kept for genetic analysis.

DNA Extraction
DNA extraction was done in the Plant Biology and Nature Management (APNA) laboratory by grinding 0.02gm of each dried sample, which was followed by E.Z.N.A SP plant DNA Mini Kit (Omega bio-tek) protocol for DNA extraction on dry samples.

Polymerase Chain Reaction (PCR)
The extracted DNA was amplified using eight *Cyperus papyrus* microsatellite loci isolate (8 pair of primers) prepared as described by Frerot et al. (2010). The PCR process was conducted using a Bio-Rad Thermal Cycler machine following the calibrated Cyppap protocol. With the cover lid maintained at 105^{o}C, the first denaturation was at 95^{o}C for 5 minutes, followed by 95^{o}C for 0.40minutes, and then annealing step was done at 54^{o}C for 1 minute and then extension at 72^{o}C for 1 minute, followed by 36 cycles at 95^{o}C for 40sec, then 72^{o}C for 10 minutes, and lastly 12^{o}C for infinite hold time. The PCR product was kept in a fridge.

Gel Electrophoresis
Thereafter fluorescent gel electrophoresis was conducted. This was preceded by denaturation of the PCR product by adding 2μl of the formamide loading dyeand 1μl of the PCR product, and then incubating it at 95^{o}C for 4 minutes.

The denaturing gel mix 6% was prepared by mixing 21g of Urea, 3.0ml of 10 × TBE, 7.5ml of Acrylamide and 50ml of Deionized water. The gel volume was 15ml with the length of 18cm, thus, 10μl of TEMED (Tetramethyl EthyleneDiamine 99%) and 100μl of 10% APS (Ammonium per Sulfate) were added to 25ml of the degassed gel mix. The computer programmes Gel Scan and ONEDscan were used to run the electrophoresis and to open the electrophoresis results (visible DNA segments), respectively. The Gel Scan was run at 40^{O}C, 1200V for 60 minutes.

Data Analysis
The genetic diversity and structure of papyrus populations were analysed by the GenAlex 6.41 software (Peakall et al., 2006) and FSTAT (Goudet, 2002); while the genotypic richness (R=G-1/N-1) was calculated by GenClone 2.0 (Arnaud-Haond & Belkhir, 2007).

Socio-economic Survey

The information on papyrus utilisation, perception of sustainability, regeneration and management practices was gathered through prepared questionnaires that consisted of about 50 questions. Thirty-three people (young <45yrs, and elders >45yrs) of both genders were interviewed. The statistical analysis was done by CANOCO 4.5 software (Ter et al., 2002). The Principal Coordinate Analysis (PCA) was performed according to the Canoco guideline manual.

Results

Clonal Diversity

There were 172 and 132 ramets, 155 and 118 genets from populations of Lake Victoria Mwanza bay and Nyanza bay respectively. The clonal diversity R was high in both regions with values ranging from 0.64 to 1 for Mwanza bay, and R 0.70 to 1 for Nyanza bay. Genetic diversity H_E was high 0.558 in Mwanza bay and 0.493 in Nyanza bay swamps.

Genetic Diversity Over the Loci - Mwanza Bay

Eight microsatellite loci were used, producing a total of 49 alleles and average gene flow (Nm) of 4 (Table 1).

Table 1: Microsatellite Loci Used in the Study and Their Descriptive Statistical Outputs for Mwanza Bay Populations

Locus	A	Ave	H_E	H_O	F_{IT}	F_{ST}	Nm
C1	6	4.21	0.564	0.755	-0.331	0.019	13.2
C3	8	5.19	0.639	0.346	0.485	0.078	2.9
C4	8	6.97	0.764	0.775	0.056	0.088	2.6
C5	7	4.42	0.359	0.425	-0.074	0.109	2.0
C10	7	5.78	0.699	0.548	0.316	0.151	1.4
C13F	5	3.83	0.496	0.485	0.067	0.065	3.6
C13S	3	2.04	0.149	0.078	0.497	0.072	3.2
C14	5	3.55	0.509	0.510	0.051	0.072	3.2
Mean	6.1		0.522	0.490	0.133	0.082	4.0
SE					0.100	0.013	1.3

Note: **A** = number of alleles, **Ave** = average number of alleles, **H_E** = expected heterozygosity, **H_O** = observed heterozygosity, **F_{IT}** = individual inbreeding coefficient relative to the total population, **F_{ST}** = population differentiation

Genetic Diversity over Loci - Nyanza Bay

A total of 44 alleles were observed (Table 2), and gene flow (Nm) ranged from 1.6 to 7.5, with an average Nm of 4.3.

Table 2: Microsatellite Loci Output for Samples from Lake Victoria Nyanza Bay - Kenya

Locus	A	Ave	H_E	H_O	F_{IT}	F_{ST}	Nm
C1	5	4.03	0.593	0.663	-0.031	0.095	2.4
C3	7	4.56	0.553	0.461	0.188	0.052	4.5
C4	10	7.81	0.826	0.872	-0.030	0.044	5.4
C5	5	4.26	0.278	0.204	0.348	0.135	1.6
C10	6	3.92	0.625	0.664	-0.007	0.073	3.2
C13F	4	2.62	0.145	0.131	0.101	0.032	7.5
C13S	4	2.89	0.353	0.236	0.351	0.056	4.2
C14	3	2.06	0.073	0.030	0.594	0.043	5.5
Mean	5.5		0.431	0.408	0.189	0.066	4.3
SE					0.080	0.012	0.7

Note: A = number of alleles, **Ave** = average number of alleles**,** H_E = expected heterozygosity, H_O = observed heterozygosity, F_{IT} = individual inbreeding coefficient relative to the total population, F_{ST} = population differentiation

Analysis of Molecular Variance (AMOVA)

The analysis of molecular variance (AMOVA) provides a hierarchical partitioning of genetic variation among populations. The AMOVA for Nyanza bay and Mwanza bay showed higher molecular variation within individuals (84% and 85% respectively) than the variation among populations and among individuals (Tables 3 and 4).

Table 3: Summary of AMOVA among Five *Cyperus Papyrus* Populations Of Lake Victoria Nyanza bay-Kenya

Source	df	Est. Var.	%	F-stat	P-value
Among Pops	4	0.156	8%	F_{ST}=0.078	0.001
Among Indiv	111	0.170	8%	F_{IS}=0.092	0.001
Within Indiv	116	1.685	84%	F_{IT}=0.162	0.001
Total	**231**	**2.011**	**100%**	**Nm=3**	

Table 4: Summary of AMOVA among six *Cyperus Papyrus* Populations of Lake Victoria Mwanza Bay Tanzania

Source	df	Est. Var.	%	F-stat	P-value
Among Pops	5	0.166	7%	F_{ST}=0.073	0.001
Among Indiv	149	0.171	8%	F_{IS}=0.081	0.001
Within Indiv	155	1.929	85%	F_{IT}=0.149	0.001
Total	**309**	**2.266**	**100%**	**Nm=3.2**	

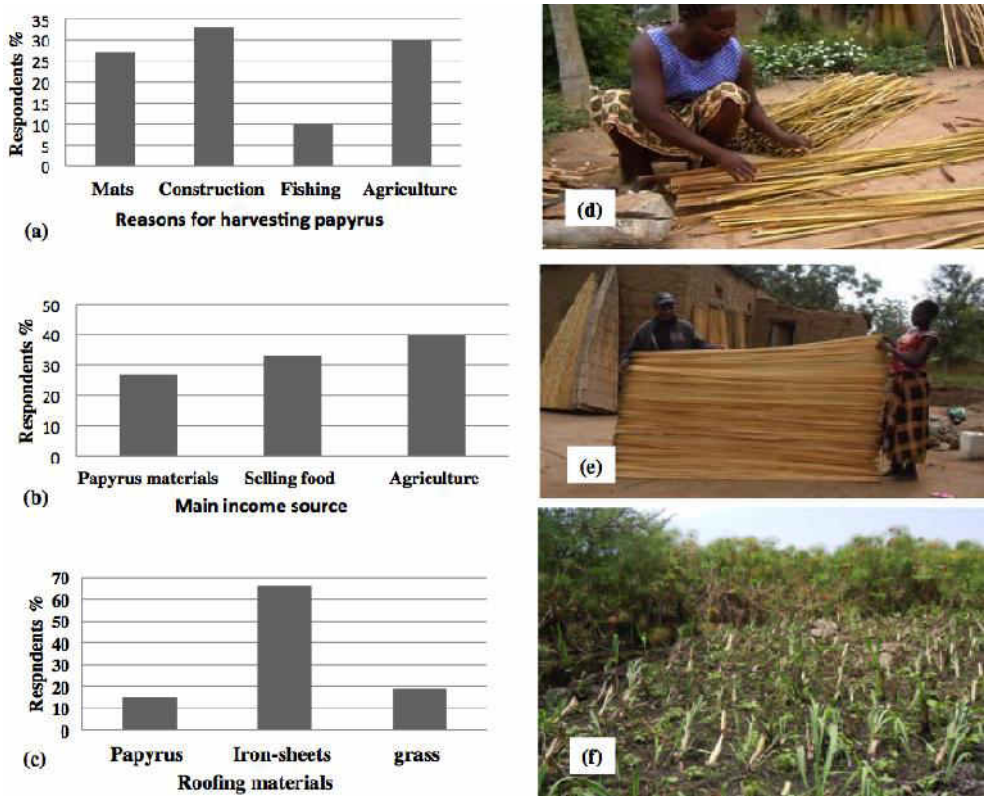
The results show a moderate genetic differentiation: F_{ST}=0.078, (p=0.001) and F_{ST}=0.073, (p=0.001) for Nyanza bay and Mwanza bay populations respectively, with an estimate of gene flow Nm=3 in each population.

Indigenous Practices on Papyrus

The field survey revealed that men and women (48% and 52% respectively), youths and elders involved in the papyrus related activities with the young group consisting of 55% while elder group 45%. Of all the people, 40% depend on agriculture as a main source of income, 33% depend on small business of selling food and fish, and 27% mainly women depend on selling papyrus products, like mats and papyrus stems, for construction.

Papyrus Utilisation

The local use of papyrus, harvesting practices and management were analysed, and PCA axis 1 accounted for 29.4% of the total variance while the second axis accounted for 46.9% of the total variance



Notes: **a** - Four main harvesting reasons, **b** - Main sources of income in selected Mwanza bay villagers, **c** - Types of roofing materials in the area, **d** - Mat making process, **e**- Ready made mat, **f**- Agriculture in papyrus swamp

Figure 4: ***Papyrus and Papyrus Swamps Utilization*****:**

The PCA results showed three groups of harvesters in Mwanza bay populations. Two groups are based on gender, with different harvesting priorities. When men mainly harvest papyrus for agriculture related activities, women harvesting practices were based on home use activities, such as making mats and for firewood. The third group includes both men and women in mixed activities of fisheries, construction and priority on swamps management practices, as shown in Fig. 5.

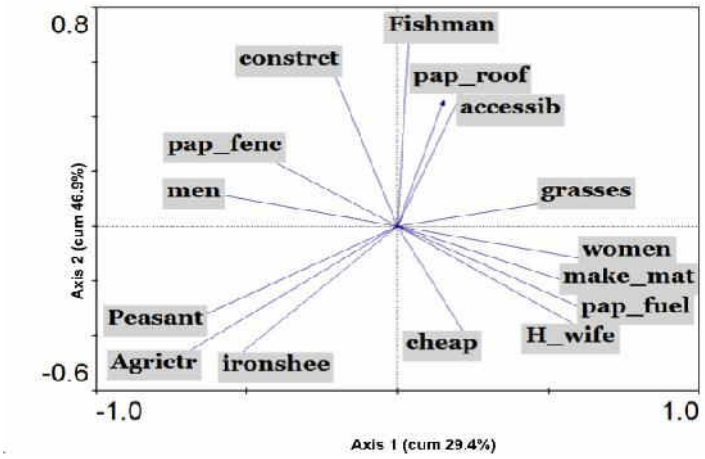


Figure 5: ***The PCA plot showing variety of priorities regarding the papyrus utilization in Mwanza bay Lake Victoria***

Discussion

The current study of eleven populations of *Cyperus papyrus* in Lake Victoria showed high genotypic diversity (R ranging 0.64 to 1), an average of 0.89, similar to the results obtained by Terer et al. (2011), which suggest that papyrus have highly successful sexual reproduction with seeds dispersal mechanism that enables the plant to colonise new areas (Ohsako, 2010; Triest et al., 2010).

Sexual Reproduction and Clonal Diversity in Papyrus

Although the average clonal diversity values are high in Lake Victoria populations, some individual populations have low values of R (KBTZ, CHGTZ and LVUS, LVKK), with higher than the average value of 21 clonal plant species, which is 0.62 for a population with limited sexual recruitment (Ellstrand & Roose, 1987, as cited by Tang et al., 2007). Although some populations were observed to be disturbed, the effect was not observed in their clonal diversity. The situation describes papyrus as highly resilient to disturbances.

Most clonal plants experience low genotypic diversity due to limited sexual reproduction. Unsuccessful pollen and seed dispersal due to seed size, negative buoyance for aquatic plants and rough sediment (Alberto et al., 2005) limit sexual recruitment while favouring clonal growth. This could be the reason for the observed low genotypic diversity in CHGTZ and KBTZ populations with rocky substrate and high water levels, respectively. The KBTZ swamp is always inundated. Therefore, the environment limits the chances for seeds to germinate, and, thus, the vegetative reproduction sustains the population (Boar, 2006). On the other hand, CHGTZ swamp is established in rocky sediments with less soil to support seedling establishment. These are part of environmental limitations for population variability (Triest, 2008). Thus, the high genetic and genotypic diversity is attributed to high gene flow within and between papyrus populations. Some clonal plants, like sea grass meadows, exhibit different levels of clonal richness from monoclonal stands (Alberto et al., 2005; Waycott et al., 1996), to a multiclonal stand (Arnaud-Haond et al., 2005). Furthermore, the current analysis of clonal diversity in *Cyperus papyrus* is comprehensive. It is a microsatellite-based study conducted with eight-microsatellite loci. Being a powerful molecular marker, microsatellite was used to avoid the introduction of both qualitative and quantitative errors, and underestimation of results, (Arnaud-Haond et al., 2005; Honnay & Jacquemyn, 2007) as advised in avoiding the use of molecular markers with less efficiency.

Although some populations were disturbed by anthropogenic activities, for example, burning, extensive harvesting and constructions, no effects of such disturbances were observed in genotypic richness and gene diversity. This suggests the ability of papyrus to reproduce sexually and resist even strong anthropogenic disturbances. According to Stocklin et al. (2009), disturbance is not always detrimental to plants because disturbance opens gaps and spaces for new seedlings to germinate, thus bringing genetic combination. Therefore, the study suggests taking precaution to the current papyrus swamps status since the current results could be attributed to events, like historical gene flow and population contacts. More information on growth strategies, seed dispersal and seedling establishment in papyrus is required to increase ecological understanding of *Cyperus papyrus*.

The local community responses to the structured questions were aimed at raising awareness of the current status of papyrus as a natural capital especially to the impoverished riparian communities (Morrison et al., 2011) and wetlands at large, with the target of incorporating management and conservation measures where the deterioration cannot be compromised. Generally, agricultural practices in wetlands were pointed out as the most

unsustainable practices. Therefore, it is useful to adapt the anthroposystem approach (Dahdouh et al., 2006) and incorporate indigenous communities and their conservation knowledge (LEK) in papers (environmental acts, conservation priorities and local authorities responsibilities) in the management and conservation plans.

The analysis of molecular variance revealed a moderate but significant population differentiation between *Cyperus papyrus* swamps within both Mwanza bay (F_{ST}=0.073, p=0.001 Nm=3.2), and within Nyanza bay (F_{ST}=0.078, p=001 Nm=3) (Tables 3 and 4). Although the two regions are far away from each other (about 800km apart of distance along the coast), they are still genetically connected (F_{ST}=0.111, p=0.001, Nm=2). When grouped as one big papyrus population in Lake Victoria (all eleven papulations), we still observed a moderate but significant population differentiation with Nm=1.7. The observed similarity between *Cyperus papyrus* populations in the present issue can be attributed to successful seed dispersal at long distances and the continuity of population contact over a long time, and historical gene flow (Hedgecock et al., 2007; Terer et al., 2011).

Some irregularities were observed regarding genetic distances and differentiation between sub-populations in both Mwanza and Nyanza bays. The populations USTZ and LUTZ, about 32km apart, were genetically closer than USTZ and MATZ populations which were less than 1km apart. Similar observation was made by Krzakowa and Michalak (2010) when they studied the common reed *P.australis* as attributed to possible gene flow pattern in the genetically related populations. The observation was also supported by population structure analysis, showing that the two populations were genetically very close, with Nm=9.5. Generally, population similarity describes the past time gene flow rather than contemporary (Hedgecock et al., 2007). This situation can be due to the geographical locations of the two related populations (Fig. 2), and the nature of water currents in the lake that transport seeds/propagules from the source to other proximities. It is thus possible that currents drifting more east southward of the channel transport seeds and propagules from USTZ to LUTZ, creating a gap between USTZ population and the nearby populations. Furthermore, the current observation can be attributed to historical gene flow as F_{ST} does not differentiate between populations with long divergent time and with recent shared history even when there is no gene flow (Pearse & Crandall, 2004). To avoid this ambiguity, a more sophisticated approach that can tell the significance of the current gene flow to the historical association among populations and demographic information on population history, growth and viability should be employed.

Papyrus Utilisation and Sustainability Take Points

This study gives information on sustainable harvesting practices, which among other things, promotes environmental sustainability concern as provided by the Millennium Development Goals (MDG 7). It combines genetics and socio-economics. The study gives way to sustainable management of wetlands and wetland resources. This helps people to alleviate poverty and make a better living.

As part of this study, the local community responses to the structured questions were aimed at raising awareness of the current status of papyrus as a natural capital, especially to the 'impoverished riparian communities' (Morrison et al., 2011) and wetland at large, with the target of incorporating management and conservation measures where the deterioration cannot be compromised. The plot (Fig. 4) demonstrates the responses we obtained from the local community questionnaire. To be more focused, men and women have different priorities in papyrus and the papyrus swamps. While men use papyrus swamps mainly for agriculture, construction and fishing; women use the resource for making mats as a source of income, for fuel as it burns quickly and it is cheap, accessible, and more important, easy to collect. Since most of the peasants earn more from agricultural activities in such a fertile wetland soil, they have their houses roofed in iron sheet and papyrus-fenced, while artisanal fishermen (normally small-scale fishermen with unsophisticated tools) have their houses thatched roofed with grass or papyrus and fenced. The current results are similar to previous studies conducted in papyrus swamps (Terer et al., 2012). Indeed, local people make their lives from papyrus through construction, cooking and warming, and selling products (like mats and agriculture) in papyrus swamps.

Agriculture in the papyrus wetlands was pointed as unsustainable. Since the wetland is perceived as an open space, the local communities themselves cannot manage the undesired practices unless the government intervenes. The lack of responsibility in the administration of people limits information flow. In the study area wetlands are taken as a common pool or open access. This might cause resource collapse if mitigation measures are not put in place at the right time (Hardin, 1968). In the presence of water, papyrus will never be exhausted by cutting for fishing activities and construction or for making mats, but clearing for agricultural activities is among the destructive practices observed in wetland ecosystems (Terer et al., 2004).

Although the frequency of destructive harvesting depends on the location of the swamp, altitude, micro and local climatic conditions (Morrison et al., 2011), papyrus harvesting regime has been intensively discussed with

different opinions on regeneration time. While some studies observed a six month regeneration interval when papyrus grows back to maturity (Dam et al., 2011), some studies suggest more time for harvesting revisit (Owino & Ryan, 2007; Terer et al., 2011, 2012; Osumba, et al., 2010). In the current study, the majority of harvesters (54%) said a one-month interval is sufficient for a second harvest, similar to other local communities (Osumba et al., 2010). Since they also reported to experience difficulties in getting the right stem size, we suggested that the time allocated for revisit of 1-6 months is too short for the plant to recover its ordinary status. Thus, this needs extension to at least 24 months as suggested by Terer et al. (2011).

In general, most of the degradation in papyrus swamps are anthropogenic, accelerated by limited knowledge of sustainable resource use. Both local community knowledge and scientific information on papyrus are of vital importance when planning for resource management since without this conservation and management strategies will not be successful (Terer et al., 2004; Dahdouh-Guebas et al., 2006). Since papyrus depends on the water level and conditions for vegetation expansion, it is not only human activities on papyrus swamps, but also natural variations in hydrological regime that reduce the papyrus covered area, which take long time to reverse.

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The Contribution of REDD Pilot Project to Community Livelihoods: A Case Study of Kondoa District, Tanzania

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Abstract

Tanzania has been implementing a project to reduce emission from deforestation and degradation (REDD). The REDD pilot project has been considered as a viable option in enhancing conservation and community livelihoods. Moreover, the contribution of REDD to community livelihoods has not been critically investigated. This study attempts to fill this information gap by using a case study of Kondoa District. The study use mixed methods to capture information from the field, including household surveys, focus group discussions, and key informant interviews. Quantitative data were analyzed using Statistical Package for Social Science (SPSS), while descriptive and content analysis were used for qualitative data. The findings reveal high awareness of the REDD pilot project by the communities. It was further observed that the REDD project has contributed income to the community from carbon sales, improved agricultural production, and has introduced income generating activities. The study concludes that for the REDD project to be successful, community participation should be strengthened in planning and designing strategies for the REDD project. It further suggests that for the REDD project to gain more support from the community, tangible benefits and more income generating activities should be given priority.

Keywords; *REDD, community, livelihoods, Kondoa District*

Introduction

Developing countries are currently in the process of establishing reduced emission from deforestation and degradation (REDD) initiatives to be able to meet the new climate regime and benefit from opportunities that REDD potentially presents. Currently, Tanzania is exploring and identifying a range of actions from pilot activities to address the drivers of deforestation (URT, 2010). The needs of local and indigenous communities should also be addressed when action is taken to reduce emissions from deforestation and forest degradation (UNFCC, 2008). Being one of the nine countries piloting

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the United Nation's REDD programme, Tanzania developed a REDD strategy in 2008 with the assistance of the REDD secretariat in the country (Burgess et al., 2010). It aims to reduce emission from deforestation, and degradation, to enhance forest carbon stock and to deliver livelihoods benefits to forest adjacent communities by rewarding them for forest conservation. There are now a number of ongoing REDD activities in the country. In addition, there is a capacity building, where UN-REDD programme in Tanzania is working in collaboration with the World Bank institute, the Forest Carbon Partnership facility and the agro-forestry centre, to conduct training and workshop on the opportunity cost for REDD (UN-REDD, 2010). Through the initiative there are several pilot projects currently going on in the country, for example in Kilosa, Lindi, Meatu, Pemba and Unguja. In these districts, community members have been practicing shifting cultivation and extraction of other forest resources, for example firewood and charcoal (Government of Norway, 2009). Kondoa District is one of the REDD pilot project by the name of "advancing REDD in the Kolo Hills forests" involving about 18,000 hectares implemented in several villages. The Project aims to reduce greenhouse gases emission as a result of deforestation and degradation. At present, REDD is seen as an opportunity to enhance support for forest conservation as well as promoting sustainable livelihood options as a way to minimize pressure on forest resources. It is argued that REDD system could offer benefits to poor people particularly in terms of increased stable and long-term financial and non-financial benefit flows to rural areas (Peskett et al., 2008).

However, the likely impacts of REDD on forest dependent livelihoods particularly the communities adjacent to the forests in rural areas, has not been critically addressed. Both climate change itself and related policies are likely to have wide- ranging effects on local communities in rural areas, particularly in developing countries (Terry, 2009). To date, forest dependent communities in rural areas have hardly featured in the international policy discourse, including UN-framework convention on climate change and its Kyoto protocol (Terry, 2009).

Current discussion on socio- economic impact of REDD is weak, with respect to community livelihoods in rural areas (Gurung, 2009). The rural communities may suffer especially from the inappropriate solution for climate change, which are being negotiated internationally. In addition, there has been inadequate empirical evidence to test this fear. Indeed, the contribution of the pilot project against its set objectives remains unclear in assessing its effectiveness (Terry, 2009). Therefore understanding the contribution of REDD on community livelihoods is important before the

implementation of a robust policy realized. This study assessed the contribution of REDD pilot projects to community livelihoods in Tanzania using a case study of Kondoa District. Specifically, the study assessed the local communities awareness of REDD projects in Kondoa district, examined the contribution of REDD projects to local communities livelihoods and suggests way to improve livelihoods benefits from REDD projects.

The Theoretical Review

Overview of REDD Projects in Africa

In sub-Saharan Africa (SSA), there have been numerous efforts to protect forest from deforestation and degradation especially in addressing rural communities' dependency on forest resources for their livelihoods (Nilson, 2005). Loss of forest in SSA is estimated to account for 12 to 17 percent per hectare annually. This causes an increase of greenhouse gas emission (Van der Werf, 2009). Through establishment of forests plantations can contributes to carbon sink which reduces the rate of emission of greenhouse gases. The REDD projects has been established and implemented in sub-Saharan African countries and elsewhere in the world. REDD in many ways can be described as a mechanism to address global market where by carbon has become a commodity that pay the forest owners for managing their forests (Gurung, 2009). It is also conceived as a simple instrument of tracking the rate of loss of forest areas and rewarding reduction in rate of loss through reducing emission from deforestation and degradation (Skutsch, 2011).

In Africa, several countries are now developing or implementing national REDD strategies. These include Ghana, Liberia, Madagascar, Tanzania, Zambia and the Congo (DRC) (Minang & Neudefeldt, 2010). Some of these REDD projects are fully operational in Africa, for example in Zambia, Ghana and Tanzania. However, most initiatives are still under pilot stages. Angelsen & Hofstad, (2008) noted that sustainable implementation of REDD projects require great link to poverty reduction and the improvement of livelihoods of rural communities whose life depends solely on forest resources. Indeed, clear property rights to determine the right and responsibility of landholder for transaction and land tenure user rights are very important for positive REDD outcomes (Angelsen, 2009). For sustainability of the REDD projects, payments for environmental resources and services in the communities may demand co-owners of common property, private or state owned land and the performance of community related forest project initiatives.

In Tanzania, the consideration of REDD project implementation is a result of National forest management policy reform of 1998 and the Forest Act of 2002 that promotes financial compensation for avoiding deforestation and

degradation by reducing the unwanted activities in the forest resources (URT, 2010). The reformed forest policy and Act emphasize about the importance of ensuring that people in rural areas adjacent to the forests, voluntarily participate in and benefits from REDD projects as an approach to enhance forest management and reduce poverty in rural areas (URT, 2009). The REDD projects should present opportunities to create new benefits from forest resources to local forest managers and incentives in exchange for the carbon credit (IPC, 2007).

However, the extent of how REDD strategy affects stakeholders participation in forest management and contribute to poverty reduction remain unclear: at the same time, sustainable forest management continues to surface in on-going international climate change regime (Schmidt, 2009). This poses the challenge whether REDD implementation will succeed in creating appropriate incentives to support local livelihoods that will ensure the reduction in the rate of loss of forest biomass (Ryan et al., 2011).

REDD and Livelihood

The livelihood approach dates back to the work of Chambers in the mid-1980s, and the concept was later developed to sustainable livelihood approach by the British Development for International Development (Collminar & Gamper, 2002). Livelihood comprises the component of capability, assets (Stores, resources, claims and access) and activities required for means of earning a living (Chamber & Conway, 1992). According to Ellis (2002), the concept of livelihoods is widely used in relation to poverty and rural development, and considered as a means of living. The livelihoods concept is adopted to express the complex processes and factors affecting livelihood of rural people. The concept linked well to the study, as REDD intends to deliver tangible benefits such as income from carbon sales, sustainable supplies of household products such as fire woods and poles from dry woods, conservation benefits at local level which might be associated with ecotourism (Vyamana, 2009). It is designed to play the role as an alternative to top down state managed approach which has been proved over the years to be associated with limited effectiveness in natural resources management (URT, 2011; Makupa, 2013).

Methods

The study was carried in 2014 in Kondoa district, Dodoma region, Tanzania (Fig. 1). The district was considered worth for the study because of being among the REDD pilot project districts in the country; and thus its contribution to rural livelihood could be easily assessed**.** The district is located between latitude 4 -12^0 and 53 -85^0 South, and longitude 35-6^0 and 36- 2^0 East of Greenwich (URT, 2009).

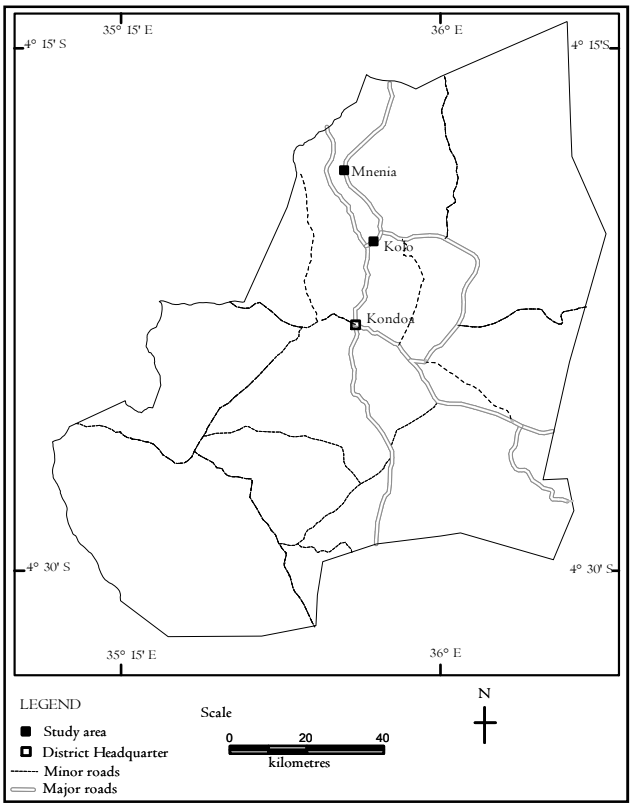

Figure 1: ***Study Area Map***

The district covers a total area of 13,210km^2, of which 50.5% is suitable for agriculture, 25.5% is under natural pasture, 16% under forest reserve, and the remaining 8% comprises of urban areas and water swamps (URT, 2012). More than 80% of the district population is employed in agricultural activities. According to the population housing census (URT, 2012), a few people are employed in formal sectors, while the majority are involved with livestock keeping and doing small businesses (kiosk type). Specifically, the study was carried in two villages, namely Kolo and Mnenia of the Kolo ward. The study villages were selected purposively based on the consideration of villages that are involved in the REDD project.

The sample size for household survey was obtained through the use of Slovin's formula, $n= N/1 +Ne^2$, where n is the sample size, N is the total number of households in the area, and e is the margin of error. Based on this formula, a total of 80 households in two villages was obtained, which presents 5% of all the households found in each of the village (Table 1).

Table 1: Sample Size

Village	No of households per each village	Total Sample size per each Village
Kolo	564	40
Mnenia	713	40
Total	**1277**	**80**

The simple random technique was employed to obtain actual household to be surveyed in the study area as the method provides equal chance for all households in the study area to be included into sample (Evans et al., 2000). The study also interviewed 8 key informants who were selected accordingto their title/job position in the study area; and were thought to be more knowledgeable about the study topic. These included village leaders from two study villages, REDD project coordinators, and district officials. Six focus group discussions were also conducted; three from each study village. Group participants were selected based on age and gender; and were categorized into three groups (youth, adult, and elders)so as to effective elicit information that respond to key research questions and capture dynamic view of respondents perception of REDD based on their age and gender. Quantitative data from the household survey were coded, entered into SPSS software for data analysis; while description and content analysis were used for data obtained from group discussions and interviews.

Findings and Discussion

The study had a total of 80 respondents of whom 80% were males and 20% were females from both villages. The reasons for male to participate more in this study could not be established. However, this could have happened by chance. Regarding the age of the respondents, the majority of the respondents (93.5%) were aged between 18 and 55 years. This indicated that most of the people were economically active. In terms of education, the majority (82.6%) of the respondents had informal or primary education. This implied that most of the villagers had low level of education which might have implication on forest resource management in the study area.

The findings about low education level of the respondents is not far from the study done by Mwakaje (2013), which indicated that majority of local communities in rural areas have informal or primary education. Thus, there is a need for intervention, like REDD+ projects (REDD+ is essentially a vehicle to financially reward developing countries for their verified efforts to reduce emissions and enhance removals of greenhouse gases through a variety of forest management options) to focus on education. This will improve people livelihoods in the study area. As for the household size in the study area, 67 % of the respondents had the size of between 1 and 6 people.

Examination of economic activities revealed that most (73.7%) of the respondents were farmers engaging in various livelihood activities including livestock keeping (45.5%) of the respondents) and some 40.6% engage in non-farm activities such as small kiosk business and timber harvesting. This suggests that a significant number of respondents in the study area depend more on the forest for subsistence and commercial gain such as selling timber, fuelwood and timber products.

Community Awareness of the REDD+ Project

The result of this study indicated that, overall, a majority (95%) of the communities were aware of the REDD+ project in their area (see Fig. 2). The high awareness could probably be due to the involvement of project stakeholders at the early beginning of the project.

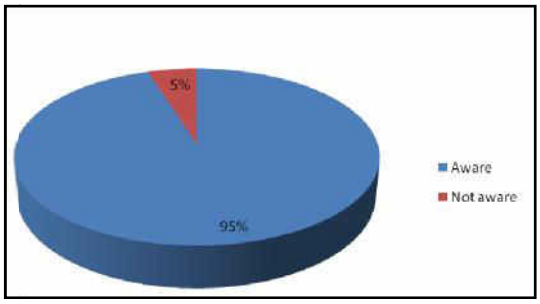

Figure 2: ***Community Awareness of REDD+ Project***

When further probed on their understanding of REDD+, overall a majority (57.8%) of the community members associated the REDD+ project with forest protection, (28.8%) with environmental protection and (13.4%) with improving community livelihoods (Table 2).

Table 2: Meaning of REDD+ project

What REDD+ meant to local communities	**Reponses in % per Villages**		**Average %**
	Kolo (n = 40)	***Mnenia (n = 40)***	
What REDD+ meant to them			
Forest protection	55	60.5	57.8
Environmental Protection	30	27.5	28.8
Improving community's livelihoods	15	12	13.4
Total	**100**	**100**	**100**

Source: Field data survey, 2014 n=sample size

During focus group discussions one discussant had this to say on the meaning of REDD+:

> *"I understand REDD+ as a project for climate change mitigation through forest protection"*

This implies that local communities in the study area were not aware of the meaning of REDD+. As mentioned earlier, REDD+ is a strategy that has been proposed in developing countries as a viable option for reducing emission from deforestation and degradation; as well as enhancing forest carbon stock in addressing climate impacts on community livelihoods. According Burges et al. (2010), REDD+ offers a significant potential for conserving forest to reduce climate the impacts change. On their part, Hirrado and Tanner (2011) considered REDD+ initiatives as a means through which local communities in developing countries can be financially rewarded through forest protection.

This mixed local perception on understanding the meaning of REDD+ projects could be due to a low awareness campaigns during the initiation of the project in the study area. Kaswamila et al., (2010) noted that various conservation practices in Africa, local communities normally remained peripheral to defining ways in which conservation is perceived, defined and managed. This is evident that although conservation projects are initiated in many areas, the local community's awareness and participation remain elusive or passive in nature. Thus, there is a need for conservation projects, like REDD+ project, to create awareness of local communities through education to ensure its sustainability and to gain support from local communities.

REDD+ and Community Livelihood

Access and Sales of Non-Timber Products

Respondents were asked whether they had an access to non-timber products under REDD+ project in the study area. Results indicate that the majority (67%) of them had an access to forest products (Table 3). This was mentioned by 73.5%, and 60.4% of the respondents from Kolo and Mnenia villages, respectively.

Table 3: Accessibility to Non-timber Product under REDD+ Project Forests

Access to non-timber products	**Residence response in terms of %**		**Average %**
	Kolo(n=40)	***Mnenia(n=40)***	
Yes	73.5	60.4	66.95
No	26.5	39.6	33.05
Total	**100**	**100**	**100**

Similar findings were revealed during group discussions, which indicate that local communities access non-timber products from the REDD+ project. This is indicted in the following statement from one discussant when responding to the question about accessibility to forest products:

> *"Non-timber products contribute significantly to the enhancement of the livelihoods of the people in our community. The REDD+ project should enhance sustainable harvesting practices by strengthening the natural resources committee of all participating villages of the Joint Forest Management."*

Respondents were further probed to mention type of non-timber products that they could access. Results indicate that these products included honey, medicinal plants and wild fruits (Table 4).

Table 4: Income from Non-timber Product fromREDD+ Project Forests

Variables	Annual Income per year per household (TZS)	Residence in %		Average %
		Kolo (n=40)	***Mnenia (n=40)***	
Honey	100,000–250,000	67.5	56	61.8
	260,000–600,000	26	31	28.5
	>600,000	6.5	13	9.8
Medicinal product	20,000–100,000	74	60	67
	110,000–200,000	20	28	24
	> 200,000	6	12	9
Wild fruits	20,000–100,000	24	21	22.5
	110,000–200,000	72	68	70
	>200,000	4	11	7.5

Table 4 above indicates income realized from non-timber products which include honey, medicinal products and wild fruits sales. On average, the income range between TZS20,000 to 250,000 per annum. This income was too low for any meaningful strategies for forest conservation. However, statistics from Kondoa District natural resource office indicated relatively a higher income from that obtained in the field. District report indicated that income realized from non-timber products was between TZS300,000 and 1,000,000 per annum. The difference in statistics could be attributed to the estimates that were made by the district officials in accordance with price value of non-timber product in the district and Dodoma Municipality.

The difference of income from that mentioned by local communities in the study villages and that reported at district level may imply that most of the value of non-timber products had not been captured in these figures. People were not very open in revealing the actual consumption and marketing of non-timber products. Findings tally with those of Mwakaje (2013) who

reported that most of the values of non-timber products have not been captured in assessing the impacts of REDD+ initiatives, simply because local communities are not aware of the actual consumption rates and market price of the products. Thus, the REDD+ project should assist the local communities in the study villages, in recognizing the value of non-timber products to people's livelihoods.

Payments from Carbon Sales

Carbon sale/exchange is carbon-based compensation mechanism for project that result in reduced carbon emissions or enhance carbon sinks or both in tropical forests. Results from this study indicated that between 2012 and 2013 carbon sales ranged between TZS5,600,000 to 7,937,200 per annum (Table 5), with Kolo village realizing the highest amount. The difference in the amount of sales was attributed to the area under forest cover, which was used to compute payments for each year. According to statistics from African Wildlife Foundation report, the area under forest in Kolo was about 1,150ha, while that of Mnenia was 900ha (AWF, 2014).

Table 5: Carbon Sales from 2012 and 2013

Village	**Sales in each year in (TZS)**	
Year	***2012***	***2013***
Mnenia	5,600,000	7,937,200
Kolo	6,400,000	6,491,821
Total	12,000,000	14,429,021

Taking into account the number of people in these villages, the amount realized per household per annum is about TZS2,000. This again is a very small amount for poverty reduction strategy. In addition, secondary data on carbon sales indicated that payment received was TZS749,998 in 2014 (African Wildlife Foundation report, 2014). These funds were used for socio-economic development, including village office building and construction of classrooms. However, the amount received is equivalent to TZS 50,122 per ha, which is less to motivate local people interest to engage in afforestation and have significant improvement to their livelihood. To improve the situation, measures should be put in place. Some of the measures could be regulation of conditions for carbon payment in compliance and voluntary market so that provision of compensation for improving livelihood to be reasonable and outweigh the cost of managing the forest. The REDD+ should direct pay the community so that they could benefit more rather than money being channeled to the state, and other non-governmental organizations. Studies by Konlan (2012) indicate that, the regulation of carbon payment conditions in a voluntary market could help the project to fair well. In other words, this could bring significant changes to people's livelihood.

Improved Agricultural Production

Statistics on the impacts of agricultural projects supported by REDD+, could not be obtained. However, the perception of local communities indicated that the initiative had helped to improve people's livelihoods. For example Kolo, 75% of respondents thought that, the agriculture project had improved their livelihood, while in Mnenia village was 66% (Fig. 3).

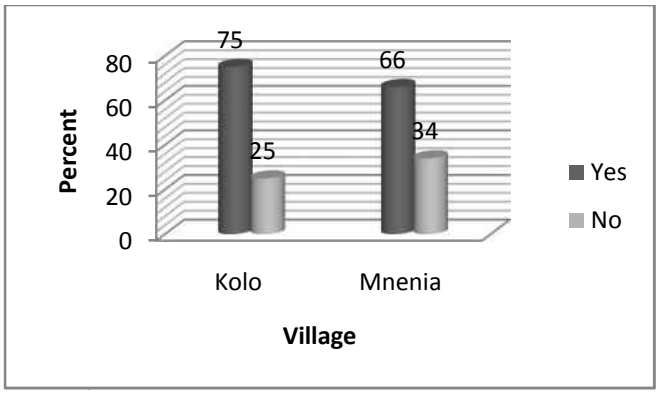

Figure 3: ***Agricultural Improvement by REDD+ project***

The perception of local communities on the initiative for improving people's livelihoods through agriculture projects can perhaps be attributed to the training of farmers on new agricultural technologies and application by farmers in agriculture activities. According to statistics from AWF office, the project used a pilot farmer approach. The project trained 173 farmers on new techniques that would help farmers to reduce the area for cultivation. This could then reduce farm expansion pressure. In addition, farmers were supported to establish and run demonstration farms, and they were given improved maize seeds (AWF, 2014). During focus group discussion, one discussant had this to say for training farmers on new agricultural technologies:

> *"The REDD+ project should build up this success and train more farmers by using current pilot farmers as trainers."*

Meaning that, farmers who were trained should be employed by the REDD+ project, to train other farmers in their area. The secondary data from the African Wildlife Foundation Report (2014) on an improved agriculture in the study area indicated that sixty farmers harvested, found an average maize yield to increase eight-fold from 30 to 39 bags/ha to 40 to 47 bags/ha in Kolo and Mnenia respectively. Thus, the additional yield have increased farmers' earning for an average of TZS640,000/= per ha. The surplus produced were

either taken to the market or sold within the village. It can be argued that REDD+ contribution to improve agricultural, is still insignificant given that there a lot of factors determining agricultural productivity. However, in order to improve agricultural activities in the study area, the REDD+ projects could facilitate the supply of agricultural inputs in the study villages including improved seeds, fertilizers and manure.

On top of that, an access to market for agricultural produce should also be taken as one of the project strategy in improving people's livelihoods in the two study villages. Since the main activity in the two villages was farming, then, even though households members tend to engage in other activities, they still kept land for cultivation. Mswima (2012) indicates that the supply of farming inputs including fertilizers and improved seeds could be one of the potential impacts of REDD+ initiative in Kilosa. This improved people's livelihoods through agricultural production. Even though farmers had been trained, there is also a need for a REDD+ project to have strategies for supplying farm inputs and facilitating access to a reliable market. This will enhance improved agricultural production. Such strategies are very important, if the market for carbon sale fails, communities could still relay their livelihoods from agricultural production instead of relay on forest resources.

Employment

From this study, statistics on employment opportunities provided by REDD+ project were also identified. Many of the respondents (53%) were not employed in various opportunities provided by REDD+ project (Table 6). Those who were employed were in agro-forestry and bricks making. During a discussion with project officials, the agro forestry was an established activity in the project area, where African Wildlife Foundation Organization (AWFO) was promoting its expansion through supporting farmers and women groups in the study villages. The AWFO have created a system of giving subsidies to agricultural inputs to farmers, and buying seedlings from the women's groups. This could attract more villagers to be employed in agro forest activities in the study villages (AWF, 2014). However, income realized from these employment opportunities could not be established.

Nonetheless, taking into account the number villagers, the percentage of those who were employed was very low to warrant any meaningful conclusion in poverty reduction. This implies that the contribution of REDD+ to community livelihoods through employment was insignificant. To improve the situation, the REDD+ project should offer more employment opportunities. These employment opportunities can include sustainable charcoal-making, fuel efficient stove-making, and fish farming. The findings about employment opportunities from the respondents was

Table 6: Activities in Which Respondents are Employed Under REDD+ Project

Employment Opportunities	Villages %		Average %
	Kolo (n=40)	***Mnenia (n=40)***	
Agroforestry	32.5	43.5	38
Brick making	10.5	7.5	9
Not employed	57	49	53
Total	**100**	**100**	**100**

not far from those of the study done by UNDP (2011), which indicated that REDD+ initiatives should contribute to the employment of many of 1.2 billion people living in extreme poverty in rural areas, who are largely poor. Thus, it is important for the REDD+ project to provide alternative means of improving people's livelihoods through employment.

Suggestions to Make REDD+ Project Effective

Respondents were further probed to propose measures that could make the REDD+ project more effective. Their responses are presented in Table 7.

Table 7: Communities Member's Suggestions to Make REDD+ Project Effective

Variable	Responseper village in (%)		Average
Mechanisms/ suggestions	***Kolo (n=40)***	***Mnenia (n=40)***	
More income generating activities	65	50	57.5
Alternative sources of energy	38.8	36.5	37.7
Enforcement of forest by laws.	30.5	33.3	31.9
Trainings on carbon assessment	25	30	27.5
Innovation and introduction of environmental friendly project.	25.6	26.3	26
Extension of project to nearby villages	17.9	2.6	10.3
Land use plan	0	10.7	5.4

Note: Data based on multiple responses, n= Sample size

Results show that an introduction of more income generating activities, the use of alternative energy sources, and the enforcement of bylaws could make REDD+ project more effective. Others include training on carbon assessments, innovation and introduction of environmental friendly projects and land use planning.

As for income generating activities, communities suggested poultry keeping, eco-tourism and aquaculture as activities that could help them generate more income in improving their livelihoods. Kajembe et al. (2003) argues that the REDD+ initiative should improve livelihoods of forest

adjacent communities through the introduction of alternative income generating activities. Regarding energy sources, communities stressed on the use of bio-gas, solar power and wind power, to mention a few. These sources are naturally found in the study area at a low cost. Thus, they could be used by many villagers in the study area at a low cost in enhancing the REDD+ forest sustainability.

Conclusion and Recommendations

REDD projects are viable options in improving local community's livelihoods through participation of all stakeholders. This study demonstrated that, in order to make REDD+ project effective and successful then, more options of income generating activities which include: eco-tourism, fish farming, poetry keeping and tree nurseries should be introduced to the communities as a way of generating income in improving people's livelihoods. In addition, usage of alternative sources of energy such as bio-gas, solar energy and wind energy could help the local communities in reducing the cost of energy in order to improve people's livelihoods. Also, conditions for carbon payments in compliance with and voluntary market should be regulated. This will enable the reasonable provision of compensation for lost livelihood opportunities from forest resources. This will reasonably outweigh the cost of protecting forests. Further, compensation programmes should consider various forms of payments whereby the community could directly benefit from those various forms of compensation rather than money being given through the state and other Non-governmental Organizations. This would help to prevent financial leakage of the REDD+ benefits targeted to local communities.

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Climate Change Adaptation Practices for Sustainable Food Production in Rombo District, Tanzania

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Abstract

Although various studies on climate change and food production have been conducted, information on how households in Tanzania respond to climate change for sustainable food production is scarce. This paper investigates climate change adaptation practices in enhancing sustainable food production in Rombo District, Tanzania. The study adopted a cross-sectional research design. Quantitative data were analysed by using the Statistical Package for Social Sciences software, while the qualitative data were analysed through factual and logical interpretation of the findings. Results show that drought was the main effect of climate change as reported by 65.7% of the respondents in the study area. Furthermore, the findings show that 81.4% of the respondents applied artificial fertilizers to their farms in efforts to adapt to climate change. Study results also show a significant association between the education level of the respondents and use of improved seeds (P = 0.08) and soil water conservation (P = 0.09) as adaptation measures to climate change. In adapting to the changing climate, respondents also experienced some challenges such as lack of resources in terms of financial, material and human labour. Proper knowledge on the adaptation measures is recommended to be given to farmers through various methods.

Introduction

The world is facing multiple crises such as hunger, poverty, economic crisis, climate change and other environmental crises. The destruction of the environment, including climate change, is the biggest long-term threat against the possibilities to end poverty, especially in aspects of hunger and malnutrition as stated in one of the targets of the Millennium Development Goal (MDG) One (UN, 2009). According to the United Nations' panel of climate experts, Africa is highly vulnerable to the impacts of climate change because of factors such as widespread poverty, recurrent droughts, inequitable land distribution and over-dependence on rain-fed agriculture (IPCC, 2001). FAO (2008) observed that in the tropical countries like Tanzania, food production is

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affected mainly by climate change impacts such as rainfall scarcity and high temperatures. Other factors include low soil fertility, poor technology, low levels of input use and poor mechanization. Normally, climate change affects food production in most developing countries that engage in the cultivation of crops in rain-fed systems. Thus, one of the great challenges of the 21st century is on how to increase food supply to accommodate the world's growing population while mitigating climate change (Easterling, 2007). Likewise, reduced food production in developing countries remains a challenge towards attaining MDGs, of which the foremost is to eradicate extreme poverty and hunger by 2015 (UN, 2008; Gregory et al., 2005).

Some studies have predicted the levels of climate change that are expected to occur in Tanzania in the coming years. For instance, according to a study commissioned by the government of Tanzania, climate change is expected to raise mean annual temperatures by 3-5ºC, and average daily temperatures by 2-4ºC by 2075 (Yanda & Moshy, 2007). It has been proposed that developing countries will be hit harder than developed countries, and the most food-insecure regions -- Sub-Saharan Africa (SSA) and South Asia -- will be hit hardest. FAO (2009) reported that by July 2009 the global total number of undernourished people surpassed 1 billion for the first time. In Tanzania specifically, out of more than 75% of people who depend on agricultural production for food and other household needs, 44% are undernourished (FAO, 2007). Due to this problem, all the development strategies conform to the commitment of the government to reduce the vulnerability of the agricultural and food security sectors to the adverse impacts of climate change (Kilembe et al., 2013). According to Yanda and Moshy (2007), the government puts a lot of efforts for adapting to climate change at both national and local levels for livestock-keepers and crop farmers.

Several studies have been conducted on relationship between climate change and crop yield (Gregory et al., 2005; Morton, 2007; Sultana et al., 2008). Despite all these studies on climate change and food production, information on how households in developing countries like Tanzania respond to climate change in order to sustain food production is still scarce. Unfortunately, food production in Tanzania, and particularly in Rombo District, is highly dependent on rain-fed agriculture, which makes the district vulnerable to the adverse impacts of climate change on crop production. This study, therefore, aims at finding out climate change adaptation practices for sustainable food production in Rombo District, Tanzania. The study specifically sought to: (i) describe the background characteristics with respect to adaptation to climate change; (ii) determine the effects of climate change; (iii) find out the adaptation practices used in the study area; and (iv) to determine the challenges experienced in

adapting to climate change. The findings of this study are expected to provide useful information to policy makers and development planners in suggesting practical tools to develop implementable policies, programmes and technologies that minimize households' vulnerability to food insecurity.

Conceptualization of Climate Change and Adaptation

Climate change and adaptation are inseparable because adaptation measures are normally taken as a remedy to changes in climatic conditions. Phillips (2006) define climate change as regional or global-scale changes in historical climate patterns arising from natural and/or man-made causes. The concept is often used synonymously with global warming and the greenhouse effect, although the concepts have different meanings. While global warming refers to any change in global average surface temperature, greenhouse effect is a natural system that regulates the temperature on earth. Global climate change facts include: increasing temperatures, melting polar icecaps, uncontrolled forest fires, and annual average increase in sea level. It is assumed that African countries that depend on natural resources and rain-fed agriculture for their economy are more vulnerable to the risk of climate change.

Adaptation has been described by Lambrou and Piana (2006) as changes in processes or structures to moderate/offset potential dangers, or to take advantage of opportunities associated with changes in climate. It also implies various actions taken to help communities and ecosystems deal with changing climate conditions. Such actions may include the construction of flood walls to protect property from sea level rise, or the planting of agricultural crops and trees more suited to warmer temperatures and drier soil conditions (Skinner, 2011; Skinner & Brody, 2011).

Methodology

The study was conducted in Rombo District, which is located in the Eastern part of Kilimanjaro Region, Tanzania. The study covered two villages, Kirongochini and Ikuini from Usseri and Mkuu divisions, respectively. The study villages were selected based on their semi-aridity conditions, and how they contribute to the district's vulnerability to food shortage. Food shortage results from crop failure due to inadequate and unreliable rainfall (URT, 2000). The study employed a cross sectional research design, which allows data to be collected at single point without repetition from a study sample. The design is also flexible in terms of data collection and less expensive in terms of time and funds (Kothari, 2004).

Multistage sampling technique was adopted whereby the sampling stages included division, village and finally the household. According to Fowler

(1993), this technique is convenient for studying large and diverse populations in which the list of actual individuals to be studied is not available, as was the case in this study. Usseri and Mkuu divisions were selected based on their climatic conditions, followed by a selection of one village Kirongochini and Ikuini from each division. Thereafter, a sample of 70 households was randomly selected from a sampling frame constructed from the village register books. This sample size was relevant according to Bryman (2004) who suggested sample of 30 units to be a minimum sample size that can be statistically tested. The respondents comprised of heads of households and some key informants: one agricultural extension officer, district agricultural and livestock development officer and four elderly people from each study village. Two focus group discussions, made up of five people, were also conducted for each study village.

Primary data were collected by using various methods such as questionnaire administration, in-depth interviews and focus group discussions. The instruments included a questionnaire, interview guide and a checklist of questions. On the other hand, secondary data was collected through documentary review of various documents on climate change, adaptation strategies and food production. Quantitative data was analysed by the Statistical Package for Social Sciences (SPSS) computer programme. Descriptive statistics such as frequencies and percentages were determined. Further analysis involved cross tabulation with Chi-square test to show association between adaptation measures and respondents' background characteristics. A qualitative method was used in the analysis of qualitative data where the use of factual and logical interpretation of the study findings was employed.

Results and Discussion

Respondents' Background Characteristics

It is important to analyse the background characteristics of a study population as it helps in data interpretation. The background characteristics involved under this study include sex, main source of income, income status, size of household and level of education.

Sex

The study findings show that 57.1% of the respondents were men, while women comprised 42.9%. This is contributed by the fact that the society in the study area is patriarchal in nature, thus the majority of households heads are men. Due to the nature of the society, it was however expected that the proportion of female respondents could be lower than what is found in this study. This was not so due to the fact that some respondents

were widows, and in some household men were not available at home during data collection, hence women had to respond on their behalf.

Main Source of Income

The study findings show that more than half (57.1%) of the respondents in the study area used both farming and animal keeping as their main source of income. The types of animals kept were mainly poultry, sheep and goats. Only 35.7% of the respondents depend on farming alone as the main source of income. The rest, 4.3% and 2.9% depend on off-farm and small business, respectively. This result shows the real image of any rural Tanzanian community, which mainly depends on farming for livelihood. This engagement of large proportion of the population in agricultural sector reflects the outcome of low education level of the rural people that denies them other alternatives for survival. It has been explained in the 2002 Household Budget Survey that 80% of the poor are rural; and 81% of the same belong to households where the main economic activity of the head of a household is agriculture.

Table 1: Distribution of Respondents by Background Variables (N = 70)

Variable	Frequency	Percent (%)
Sex		
Male	40	57.1
Female	30	42.9
Main source of income		
Crop farming and animal keeping	40	57.1
Crop farming only	25	35.7
Crop farming and off farm activities	3	4.3
Crop farming and small business	2	2.9
Income status		
Low	45	64.3
Medium	25	35.7
High	0	0
Household size		
1-3	8	11.4
4-6	43	61.4
7-9	17	24.3
10 and above	2	2.9
Level of education		
4 years in primary schooling	10	14.3
Completed std. Seven	45	64.3
Completed form four	4	5.7
Never attended school	11	15.7

Source: Field survey, 2010

Tanzania has recently recognized that agriculture plays a pivotal role in the reduction of poverty through increased food production. This recognition made the government in 2009 to embark on agricultural production improvement by its famous slogan of *Kilimo Kwanza,*[1] to realise a green revolution. Among the activities in pillar number one of the ten pillars of Kilimo Kwanza is to modernise and commercialise agriculture for peasant, small, medium and large scale farm producers (RAWG, 2009)., Under *Kilimo Kwanza,* farmers expect to get subsidies that will assist them in cash crop production. However, the practise of subsidising farmers had been in existence in Tanzania for some years, but was abandoned in 1980s and 1990s due to policy reforms, introduced in the form of Structural Adjustment Programmes (SAPs). Specific measures were taken in 1993/94 when prices of cash crops were decontrolled by the government to allow private traders and institutions to participate in the marketing of the crops (Ponte, 2001).

Household Income Status

According to the results of this study, there were only two categories of income status; low (less than TZS50,000 per month),[2] and medium income level (between TZS50,000 and 150,000 per month), which comprised 64.3% and 35.7% of the respondents, respectively. The findings show that there was no respondent with high level of income status (more than TZS50,000 per month). This portrays the actual situation of the rural poor who depends on peasantry farming as a source of income. The low levels of income forces households of poor peasants to consume less. For instance, the Poverty and Human Development Report of 2009 puts it that almost 98% of households spend less than TZS58,000 per month per adult equivalent on food and basic necessities according to 2007 prices, and approximately 80% spend less than TZS38,600 per month. This situation is a result of too much dependence on agriculture, which is the least remunerative sector in the economy (RAWG, 2009).

Household Size

Study results show that 61.4% of the respondents had a household size with a number of people ranging from 4 to 6 members. On the other hand, only 2.9% of the respondents had a household size above 10 members, while the remaining 11.4% and 24.3% had a household size ranging from 1 - 3 and 7 – 9, respectively. This finding deviates from the district average household size, which is 4.4 according to the national census (URT, 2013). This could be due to the small sample size used. Large household size is expected to contribute to increased food production by working together in household economic activities. However, this could be possible when almost all of the household members take part in the production process.

[1] A Swahili name meaning Agriculture first

[2] 1USD was equivalent to approximately TZS1500 during the study time

Level of Education

The study findings show that 64.2% of the respondents had completed primary education, while only 5.7% had gone beyond primary education. Of the rest (14.3%) had stayed in primary school only for four years, and 15.7% had never attended school. These results depict the actual situation in most rural areas of Tanzania, where the majority have never attended secondary education. However, since the majority had formal education, this implies that they were literate enough to learn and use various adaptation measures provided through different sources such as mass media, agricultural extension agents and publications.

Education is expected to provide knowledge to people on how to adapt to climate change for sustainable food production. It is believed that educated people have greater access to information on climate change, improved technologies and higher productivity techniques. It has been argued by Kilembe et al. (2013) that if efforts are made to ensure that the young generation is well educated, there will likely be increased capacity to deal with the challenges of climate change to the agricultural sector. Despite the significance of education in adapting to climate change, it has been revealed that secondary school students do not understand the interconnections among the components of the climate system (Shepardson et al., 2012). This knowledge gap is a significant stumbling block for understanding not only the causes and effects of climate change, but also the adaptive and mitigation strategies that can be developed.

Effects of Climate Change

The study results show that 65.7% of the respondents mentioned drought as the main effect of climate change in the study area, followed by unreliable rainfall, which was reported by 30% of the respondents. Other effects were storm waters and outbreak of pests and diseases as reported by 2.9% and 1.4% of the respondents, respectively (Table 2).

Table 2: Distribution of Respondents by the Effects of Climate Change (N = 70)

Effect	Frequency	Percent (%)
Drought	46	65.7
Unreliable rainfall	21	30.0
Storm waters	2	2.9
Outbreak of pests and diseases	1	1.4
Total	**70**	**100**

Source: Field survey, 2010

From these findings, drought is the major effect of climate change due to the fact that people in the study area perceives climate change as reduction in amount of rainfall, together with the changes in duration of rains. In this respect, people had the idea that droughts in recent years are more severe than in the past. The respondents claimed that droughts repeat after 2 to 3 years, while in the past it could repeat after 6 to 10 years. They further claimed that droughts are usually accompanied with severe food shortage as majority of households' food consumption depends directly on what they produce from their farms.

With regard to unreliable rainfall, respondents were highly food unsecured in the study area as narrated by one key informant in Box 1.

BOX 1: RELATIONSHIP BETWEEN RAINFALL AND HOUSEHOLD FOOD AVAILABILITY

When there is enough rainfall, household food is also sufficient but the crops are sold at very low prices. The reverse is also true; when there is insufficient rainfall, household food availability becomes an issue and the food prices boom. In my case for example, I put all my efforts in agricultural production but lack of rains lets me down. Nowadays it is not possible to have assurance of harvesting in order to have enough food for the household consumption and surplus to sell to meet other needs. As a farmer I do not have anything else to sell in order to meet my basic needs. So I found compelled to sell the food I produce even if it is not enough for household consumption. Consequently, my household always suffers from frequent food shortages.

Although outbreak of pests and diseases was mentioned by one respondent only, it also came out during focus group discussion. The group participants claimed that banana production has been affected by the outbreak of insect pests such as black ants, which destroy roots and stems of banana plants. It is possible that food production can be affected by other factors like deteriorating soil fertility due continuous use of the same land for cultivation, low use of inputs, destructive animals and small farm size due to population increase. However, in the case of this study rain shortage is the more striking factor that threatens maize production in the area. All these effects of climate change make farmers to adapt to some practices to ensure sustainable food production as discussed in the next section.

Adaptation Practices towards Climate Change

The study results show that farmers in the study area were forced to change their traditional way of crop production due to climate change. By so doing, they sought to adapt to some practices as shown in Table 3.

Table 3: Distribution of Respondents by Adaptation Practices (N = 70)

Practice	Frequency	Percent (%)*
Use of fertilizers	57	81.4
Use of improved seeds	43	61.4
On-farm rain water harvest	33	47.1
Crop diversification	13	18.6

Notes: *Percentages add up to more than 100 due to multiple responses
Source: Field survey, 2010

According to the results, a majority (81.4%) of the respondents mentioned the use of fertilizers as the main adaptation practice; followed by the use of improved seeds, which was mentioned by 61.4% of the respondents. Other practices were on-farm rain water harvest and crop diversification, which were mentioned by 47.1% and 18.6% of the respondents, respectively.

Use of Fertilizers

According to focus group discussions and key informant interviews, the use of fertilizers was not practiced in the past. This was because the farms were fertile enough to support plant growth and obtain sufficient crop yield. Application of fertilizers is one of the inputs that enhance crop productivity when appropriately used and supported with sufficient soil moisture content. However, the use of fertilizers, although mentioned by the majority of respondents as one of the measures to adapt to climate change, is not easily affordable especially for the poorest farmers. Although the government introduced a voucher system through which fertilizers were sold at cheaper prices, farmers were just buying some small amounts of fertilizer that they could afford, but not sufficient for their farms.

It has been argued in RAWG (2007) that the cost and availability of fertilizers and other agricultural inputs have been the major hurdles in agricultural production in Tanzania. Although the use of manure as an alternative to artificial fertilizer could be cheaper, it was unfortunate that the respondents in the study villages (Kirongochini and Ikuini) could not opt for it. They were poor farmers in the low land area of Rombo District, who mostly keep poultry and very few animals like goats and sheep, which were not capable to produce enough manure.

Use of Improved Seeds

The respondents argued that this practice was used after they had noted that there are some changes in the duration and amount of rainfall in their area. They also decided to use improved seeds after they had observed that households that use modern seeds tend to have high chance of harvesting

than those that use traditional seeds. Improved seeds are essential components in increasing productivity in agriculture. The seeds include two categories: (i) higher yields with greater resistance to pests and diseases; and (ii) shorter crop duration varieties. This practice is especially important in countries like Tanzania, where the agricultural sector is dominated by small subsistence farmers who cannot afford other more costly practices. However, the cost element also appears here again, thus not all farmers were able to apply this practice, unless assisted by the government.

On-farm Rain Water Harvest

Rain water harvesting was done either by directing run-off water from roads to farms, or by the use of terraces as a mechanism to retain rain water in farms. The use of terraces helped to reduce the speed of run-off water and allow rain water to penetrate into the soil for plant use instead of wastage in the form of storm water. The two traditional practices were developed by farmers as a response to rain shortages and frequent droughts. They involve harvesting surface run-off water and increasing water infiltration into their farms. The intention was to increase soil moisture content, and at the same time reduce flash floods that occur during heavy rain seasons.

Crop Diversification

Crop diversification as an adaptation measure to climate change by the respondents involves cultivation of a variety of crops like cassava, pigeon peas, groundnuts and sunflower, which were not traditionally grown in the study area. Cassava, for instance, was believed to be poisonous in the past, thus people were not using it as food. Rarely, it was dried up during food shortages and used as flour for stiff porridge by some very poor families. The study further discovered that people in the study area had changed their staple food from banana based meals to cereal based meals, mostly maize, for a long time. This was attributed to the fact that banana production has been affected by climatic change such as decrease in rainfall and frequent prolonged drought. Thus, other crops were introduced after discovering that maize production alone was not sufficient in dealing with the problems of food shortage. The respondents reported that they currently concentrate on the production of cassava and maize as alternative staple crops to banana. This is in line with Orindi and Eriksen (2005) who found out that crop choice is climate sensitive, and farmers adapt to changes in climate by switching crops.

Association between Adaptation Measures and Background Characteristics

It was also revealed from cross tabulation that there was an association between the level of education of respondents and taking measures for adaptation to climate change. The Chi-square test results indicated that

there was significant association between the education level of the respondents and the use of adaptation measures to climate change such as the use of improved seeds (P = 0.08) and on-farm rain water harvest (P = 0.09). This implies that education increases climate change awareness and the likelihood of taking some adaptation measures to enhance food security. Thus education is an important asset in enabling poor people to come out of poverty, especially in the face of climate change. It is expected that the impact of climate change on people's livelihoods will require people being innovative, for example, by adopting modern production technologies for higher food crop productivity in agricultural. However, the Chi-square test results revealed no significant association between the adaptation measures and other background variables.

Challenges in Adapting to Changes in Climate

The results in Table 4 show that 51.4% of the respondents reported that households fail to adapt to climate changes primarily due to the lack of resources. These resources include financial, material and human labour. Lack of financial resources in terms of households' own cash, or in the form of credit, was claimed by the respondents to hinder household's ability to adapt to climate change. This is due to the fact that many adaptation activities involve the use of money, especially in buying some inputs like fertilizers and improved seeds to enhance crop productivity.

Table 4: Distribution of Respondents According to Challenges In Adapting to Climate Change (N = 70)

Challenge	Frequency	Percent (%)
Lack of resources	36	51.4
Lack of awareness	22	31.4
Irresponsible behaviour	9	12.9
Others	3	4.3
Total	**70**	**100**

Source: Field survey, 2010

Furthermore, 31.4% of the respondents said that the lack of awareness about climate change was the challenge in adapting to changes in climate. These respondents said that they lack information on climate change impacts and adaptation options. Due to this, some people get satisfied with the changes and claim that these are according to God's will, as revealed by one key informant who claimed that the solution for adverse climate changes is to pray more to God for His mercy. Another key informant further said that in the past they were used to offer sacrifices to the ancestors, asking for forgiveness and favour and they were heard; but currently they have stopped performing such kinds of rituals due to interventions from religious people who preach that the performance of the rituals are against God's will.

Additionally, about 13% of respondents mentioned irresponsible behaviour as one of the challenges. This is the tendency of some people to ignore things in their surroundings even if they interfere with their livelihoods. In this case it means some people have noted that there are some changes in rainfall in terms of onset and distribution but they may not take any initiative to cope with the changes.

Other challenges such as small size of the farms, old age and superstition were mentioned by 4.3% of the respondents. They claimed for example that they fail to plant variety of crops because their farms are small. This is the problem in the study area that land fragmentation is very high due to population growth and low mobility of the poor households. Consequently, high population pressures force farmers to intensively farm small plots of land, making it difficult to adopt adaptation practices, such as planting trees, which require more land. Old age as another challenge was mentioned in the sense that some of the adaptation measures involve intensive land management, for example making terraces for rain water harvests is laborious work for the aged ones.

On the side of superstition it was lamented that some people associate the shortage of rains with some beliefs that some people have the power to inhibit raining. As a result they take no action of adapting with the expectation that when those people in power are pleased with some offerings then the rains will fall as usual and they will have good harvests. This shows that people are not aware with the climatic change that is why they tend to associate the changes with some beliefs. It implies that these people need to be informed of the climatic changes.

The challenges identified under this study are common, not only to the study area but in most developing countries. For instance, Kilembe et al. (2013) in a comprehensive analysis of East African agriculture and climate change identified challenges commonly faced that limit adaptation to climate change such as weak infrastructure and economies; the dependence of food security on rainfall; severe poverty and deteriorating livelihoods; limited reliable, accurate, and updated statistical information; only to mention a few. The author added that a major challenge is increasing agricultural production among resource-poor farmers without exacerbating environmental problems and simultaneously coping with climate change.

Conclusion and Recommendations

Climate change results in large losses in productivity of food crops in various parts of Tanzania. Hence, communities need to adapt to climate change in order to attain sustainable food production at both local and national levels,

notwithstanding the various challenges they experience. The occurrence of climate change in Rombo District has made people to change their traditional food production practices as one of coping measures.

Since adaptation measures are associated with literacy level, it is important to ensure that proper knowledge on the measures is given to farmers through various methods such as the use of radio, television or provision of seminars. Knowledge can also be imparted to students at various levels of education by incorporating in the syllabus a topic on climate change. Furthermore, the government, through sectoral policy formulation, should give sufficient account on climate change adaptation practices. This can be achieved through conducting site-specific studies to facilitate the attainment of relevant information on how the community responds to the situation of low food production as a result of climate change. The government should also give enough support to the agricultural sector, especially in assisting poor farmers through the provision of subsidies.

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