ISSN 0856-4965

The Tanzania Forestry Research Institute

(TAFORI)

Newsletter

Vol. 8 No. 2 December, 2017

Published by Tanzania Forestry Research Institute (TAFORI)

P.O. Box 1854, Morogoro, Tanzania

Tel: +255 23 2604498/2604532

Fax: +255 23 2603725

E- mail: tafori@tafori.or.tz

Website: www.tafori.or.tz

COVER

Women carrying fodder from AF plots far from home.

Table of Contents

TAFORI Newsletter is published twice a year by Tanzania Forestry Research Institute. Contributions to the Newsletter are invited from members of the public having relevant information about forestry research and development in Tanzania. The views expressed in the TAFORI Newsletter are those of the authors and do not necessarily represent the views of the Editorial Board or any other establishment associated with TAFORI.

WOODY SPECIES COMPOSITION, DOMINANCE, BASAL AREA AND DIVERSITY IN AGROFORESTRY PLOTS; CASE OF LUSHOTO DISTRICT, TANZANIA

[1]Mndolwa, M.A., [1]Kagosi, P.J., [1]Japhet, E.M., [2]Sabuni, F. and [2]Kirenga, R.

[1]Tanzania Forestry Research Institute, P.O Box 1854, Morogoro.

[2]Eastern Arc Mountain Endowment Fund, P.O. Box 6053, Morogoro

Correspondence author email: *emajaphet@yahoo.com*

ABSTRACT

The ecological benefits of Agroforestry (AF) systems dependent on a number of factors including type and arrangement of woody species, density and type of crop planted. The aim of this study was to assess woody species composition, dominance, basal area and diversity in AF plots in Lushoto district. Four villages practicing AF, i.e. Migambo, Kwembago, Kinko and Mavumo were purposively selected for both biophysical and socio-economic data collection. Socio-economic data were collected using focus group discussions and questionnaire. For collection of biophysical data, one transect was established across each village. A total of 60 quadrats (20m x 20m) were laid in AF plots along the four transects. In each quadrat woody species with Diameter at Breast Height (DBH) ≥5cm were numbered, counted, identified by species and assessed. The dominant tree species were determined on the basis of their Important Value Index (IVI) and species diversity by Shannon-Wiener diversity index (H’). Results showed that the most (61%) practiced AF was agri-silviculture. Some 20 families comprising of 27 woody species were recorded. *Grevillea robusta* was a dominating contributing 29% of the total tree species in the study area. The species also had the highest (70.1) average IVI. The mean trees' basal area within AF plots was 2.83m^2/ha with average Shannon-Wiener diversity index (H’) of 1.86. The study concluded that current levels of species composition, dominance, basal area and diversity in AF plots are capable of providing acceptable ecological benefits. However, increasing number and species of tree component in AF plots is recommended.

Key words: Agroforestry, Basal area, Species diversity, Woody species composition

INTRODUCTION

There are various definitions of Agroforestry (AF). However, the definition given by Lundgren and Raintree, (1982) cited by Nair (1993), provides a clear and practical definition of AF. Lundgren and Raintree (1982) defined AF as a collective name for land-use systems and technologies where woody perennials (eg. trees, shrubs, palms, bamboos) are deliberately planted on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. AF is a dynamic ecologically based natural resources management system that sustains production (Molla and Kewessa, 2015). In their combination, trees and crops (components) take advantage of interactions between them in the farming system. In AF, species composition is one of major components of biologically spatial structure (Huang *et al.*, 2003). The presence of various trees and shrub species improves the value of AF. For example, the presence of herbaceous food resources has been reported to improve honey production and bees diversity (Hoehn *et al.*, 2010). On the other hand, soil organic carbon content was found to be positively correlated with both tree density and species richness (Islam *et al*., 2015). Islam *et al.* (2015) further reported that species-rich AF technologies like homegarden with high tree density can sequester more carbon in soil thereby contributing more to climate change mitigation.

Originally, AF within Lushoto district involved the use and protection of trees and shrubs by farmers in agricultural landscapes (Dawson *et al*., 2013) for fodder, fuel wood, medicines and building materials (Scherr, 1990). Farmers retain various tree components based on spaces available and their compatibility with agricultural crops and household needs (Mekonnen *et al*., 2014). This was considered an important step in conserving tropical trees (Dawson *et al*., 2013). The study by Namwata *et al.* (2012) in Lushoto district revealed that AF systems have potential for their high level of productivity. Through the time, AF transformed into present various technologies. Among the technologies, homegarden has become a popular land-use in Lushoto district. It was reported that, the homegarden supports sequestration of organic carbon in soil more than crops, monoculture plantations and even other AF systems (Islam *et al*., 2015). The system is believed to be more diverse due to combination of crops, trees and livestock (Mekonnen *et al*., 2014).

AF has been considered to have high diversity. For example, the study by Mwangoka *et al.* (2010) reported that in some cases diversity level of AF systems is as higher as those of natural forests. Normally, diversity is influenced by presence of one or more species with higher frequencies of occurrence. It is important to consider species and growth patterns of various tree components in AF as species diversity is significantly associated with structure and species composition (Huang *et al*., 2003). Various scientists accept that diversity of trees is fundamental to total trees biodiversity (Huang *et al*., 2003). This paper highlights on woody species composition, dominance, basal area and diversity in AF plots in Lushoto district.

MATERIALS AND METHODS

Description of study area

The study was conducted in Lushoto district in purposively selected four villages practicing AF namely Migambo, Kwembago, Kinko and Mavumo. The district is found within longitudes 38^o 05’ and 38^o 38’E and latitudes 4^o 22’ and 5^o 08’ S and altitude ranging from 600 - 2300 meters above sea level (Huwe and Mwihomeke, 1990). The area has relatively cool and less humid climate with maximum temperatures in March and minimum in July (Wiersum *et al*., 1985). During cold seasons temperatures may go down to 8^{o}C while 30^{o}C are common during hot seasons (Nasser *et al*., 1993). Lushoto district receives mean rainfall of 800 - 2,000 mm in the highland and between 500 - 800 mm per annum in the lowlands. Long rains fall between March and June and short rains between October and December. The district receives some intermediate rains between July and September. The study villages were in the highland.

The district has considerable relief with steep slopes (Kihiyo, 1985). The larger part of the district has deep red earth soil and intermediate metamorphic rocks with surface pH of 5.85 (Maro *et al*., 2014). The seasonally flooded soils of the lower valleys are quite deep and fertile with a loamy, blackish – brown alluvium. Some patches of Montane forests are found within the district (Hamisy and Mathias, 2001). The major economic activities in Lushoto district are mainly agriculture, livestock keeping and small businesses.

Data collection and analysis

Data collection

Four villages Migambo, Kwembago, Kinko and Mavumo practicing AF were purposively selected for both biophysical and socio-economic data collection.

(i) Biophysical data collection

One transect along the gradient was established in each village to cover altitudinal variations. GPS was used to locate data collection quadrats. A total of 60 (20m x 20m**)** adopted from Molla and Kewessa (2015) were systematically laid along the transect in AF plots. In each quadrat woody species (trees and shrubs) were marked and recorded in the field for their occurrences and identified for their respective botanical name by the botanist. All trees with Diameter at Breast Height (DBH) $\geq$ 5 were numbered, counted and identified by species (Huang *et al.*, 2003). Collected data included; number of individual tree/shrub species, DBH and specie's name.

(a) Tree/shrub species composition and dominance

- **Tree/shrub species composition**

Identified individual tree species were arranged alphabetically in spreadsheet and thereafter the list and number of species in the AF plots was obtained.

- **Tree/shrub species dominance**

The dominant tree species were determined on the basis of their Important Value Index (IVI). The IVI gives a combined standard measure of abundance, density and dispersion for each species (Kent and Coker, 1992). It is a composite index based on the relative measures of species frequency, abundance, and dominance and it indicates the significance of species in the system (Molla and Kewessa, 2015). The higher the IVI the more ecologically dominant and important the tree species is in a given plant community (Shrestha *et al*., 2000; Reddy *et al*., 2008). The IVI for each individual tree species was determined using the formula recommended by Mueller-Dombois and Ellenberg (1974).

$$IVI = (RD + RDo + RF) \qquad (1)$$

Where:

RD = 100 × number of individuals of the species/number of individuals of all species

RDo = 100 × total basal area of the species/ total basal area of all species

RF = 100 ×number of occurrence of the species/number of occurrences of all species

(b) Tree Species diversity

Shannon Wiener Index (H') was used to determine species diversity of woody perennials in the AF plots. The index accounts for both abundance and evenness of the species present where two components of diversity are combined (i) the number of species and (ii) equitability or evenness portion of individuals among the species (Molla and Kewessa, 2015). The index is described mathematically as follows:-

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \quad \ldots\ldots (2)$$

Where;

H' = Shannon–Wiener index

P_i = the proportion of all individuals in the sample that belong to species i

S = total number of plant species

Ln = $\log_e$ = natural logarithm of pi (e = 2.71828).

$P_i = \frac{n_i}{N}$

Where; n_i = total number of individuals in the i^{th} species

N = total number of individuals of all species

The Shannon Wiener index assumes that all the species from the community are included in the samples. The value usually lies between 1.5 and 3.5 although it can occasionally exceed 4.5 (Kent and Coker, 1992). High value of H' indicates high diversity.

(ii) Socio-economic data collection

Socio-economic data were collected using focus group discussions and questionnaire methods. This data were collected to supplement biophysical data and information.

RESULTS AND DISCUSSION

It was observed that types of AF practiced were influenced by farm sizes. In general 75% of the households reported to own less land than what they need. Sixty three percent of the households had less than 2 acres while 37% had more than 2 acres. The most popular (61%) AF practice in the study area was agri-silviculture. Agri-silviculture, api-silviclture, woodlots, boundary planting, agri-silvi-pastoral and home gardens were commonly practiced in Migambo and Kwembago villages, while alley cropping, woodlots, agri-silviculture, boundary planting and api-silviculture were common in Mavumo and Kinko villages. In common, woodlots was less practiced in all villages. Agri-silvipastoral was common in Mavumo and Kinko villages because 41% households in these villages have relatively larger pieces of land (>2ha) against Migambo and Kwembago who in average 30% have >2ha.

Woody species composition in AF plots

A total of 27 (22 trees and 5 shrubs) woody species belonging to 20 families (**Table 1**) were recorded within AF plots in the study area. The recorded woody species were far less than those (44 woody species) found in homegarden in Ethiopia (Mekonnen *et al*., 2014), 45 tree species recorded by Munishi *et al*., (2006) in farm tree retention in Bumbuli ward in Lushoto district and 55 woody species belonging to 31 families gathered in traditional AF plots in Ethiopia (Molla and Kewessa, 2015). Table 1 below shows a list of trees and shrubs found in AF plots in the study area.

Table1: List of woody species (trees and shrubs) found in AF plots

Species	Type	Family	Species	Type	Family
Acrocarpus fraxinifolius	Tree	Caesalpiniaceae	*Juniperus procera*	Tree	Cupressaceae
Albizia schimperiana	Tree	Leguminosae	*Olea capensis*	Tree	Oleaceae
Annona spp	Tree	Annonaceae	*Persea americana*	Tree	Lauraceae
Brassica spp.	Shrub	Brassicaceae	*Persea domestica*	Tree	Pinaceae
Citrus spp.	Tree	Rutaceae	*Pinus patula*.	Tree	Pinaceae
Croton spp.	Tree	Euphorbiaceae	*Prunus persica*	Tree	Pinaceae
Cupressus lusitanica	Tree	Cupressaceae	*Prunus domestica*	Tree	Rosaceae
Dioscorea spp.	Shrub	Dioscoreaceae	*Prunus japonica*	Shrub	Rosaceae
Ficus spp.	Tree	Moraceae	*Psidium guajava*	Tree	Myrtaceae
Grevillea robusta	Tree	Proteaceae	*Rauvolfia caffra*	Tree	Apocynaceae
Eriobotrya japonica	Tree	Rosaceae	*Solanum gilo*	Shrub	Solanaceae
Euclea fructuosa	Tree	Ebenaceae	*Tectona grandis*	Tree	Lamiaceae
Eucalyptus spp.	Tree	Myrtaceae	*Turraea robusta*	Shrub	Meliaceae
E. Saligna	Tree	Myrtaceae			

Generally *G. robusta* was a dominating tree species in all villages contributing 29% of the total tree species. The least occurring included; *T. grandis* and *Ficus* spp (0.5% each), *A. schimperiana*, *Annona* spp., *Dioscorea* spp, *O. capensis* and *Brassica* spp. (with 0.6% each). *Acrocarpus* spp, *Prunus domestica* and *C. lusitanica* were found in Migambo and Kwembago villages only while *Euclea fractuosa, O. capensis* and *Brassica* spp were found in Kinko and Mavumo villages. It is reported that different traditions and different agro-ecological conditions dictate the type of tree species that are likely to be accommodated on farm (Munishi *et al.*, 2006). Presence of many woody species in AF plots provides various woody products for households livelihood need (e.g. fuelwood, medicine, fodder and timber) and improves stability of the AF ecosystem. On the other hand, species abundance in AF plots is a function of either household preference or best fit to the given ecology /climate (Mekonnen *et al*., 2014).

Tree species dominance

In general *G. robusta* had the highest average Importance Value Index (IVI) of 70.1 in the study area. *G. robusta* was dominating in Kinko village *C. lusitanica*, *P. japonica* and *P. americana* dominated in Mavumo, Migambo and Kwembago respectively. The most dominant tree species by the (IVI) in Kinko village were *G. robusta, J. procera* and *P. persica* while in Mavumo village were *C. lusitanica, G. robusta, P. americana* and *P. patula.* The most dominant tree species in Migambo village were *P. japonica, G. robusta, P. americana and S. gilo* while in Kwembago village were *P. americana, G. robusta, P. patula* and *A. schimperiana* (Table 2). The higher Importance Value Index for these tree species is an indication that they have wide range of growth, adaptability and evenly distributed in the AF systems (Reddy *et al*., 2008). The dominant species were ecologically dominant and important tree species in AF communities as the higher the IVI the more ecologically dominant and important the tree species is (Shrestha *et al*., 2000; Reddy *et al.*, 2008).

Table 2: The Importance Value Indices (IVI) of dominant tree species in the study area.

Village	Botanical Name	IVI
Kinko	*G. robusta*	155.52
	J. procera	22.93
	P. persica	11.76
Mavumo	*C. lusitanica*	124.93
	G. robusta	30.70
	P. americana	28.39
	P. patula	27.69
Migambo	*P. japonica*	73.79
	G. robusta	48.07
	P. americana	38.86
	S. gilo	16.18
Kwembago	*P. americana*	56.38
	G. robusta	46.19
	P. patula	35.01
	A. schimperiana	30.41

Tree basal area

It was found that the mean trees' basal area within AF plots was 2.83m^2/ha. Being the dominant tree species, *G. robusta* had the highest basal area of (0.91m^2/ha) (Table 3). Nine species had basal area of less than 1.0m^2/ha. It was learnt that some of these woody species like *O. capensis* and *T. grandis* were poorly site matched. The average basal area obtained from this study was much lower than that (21m^2ha^{-1}) reported by Munishi *et al*. (2006) from trees on farm at Bumbuli. The lower basal area might have resulted from the fact that many trees in the study area were young average basal areas per individual trees in the study area.

Table 3: Average basal area of individual trees/shrubs with basal area >0.02 m^2ha^{-1}

Species	Stems/ha	Basal area (m^2ha^{-1})	Species	Stems/ha	Basal area (m^2ha^{-1})
Acrocarpus spp.	2.9	0.07	*P. americana*	16.3	0.53
A. schimperiana	4.1	0.16	*P. patula*	15.8	0.12
Citrus spp.	2.1	0.05	*P. domestica*	2.5	0.02
Croton spp.	4.5	0.03	*P. japonica*	22.9	0.08
C. lusitanica	22.1	0.31	*P. persica*	11.7	0.02
E. japonica	2.5	0.03	*S. gilo*	7.1	0.02
Eucalyptus spp.	2.9	0.02	*Turraea robusta*	9.6	0.14
G. robusta	43.3	0.91			

Despite the fact that the overall basal area is very low but in terms of density aggregate woody species density was as high as 182 stems/ha. This is higher than 147 stems/ha reported by Munishi *et al.* (2006) in Bumbuli.

Tree Species diversity

Tree species diversity within study area averaged Shannon-Wiener diversity index (H') of 1.86. It is accepted that an ecosystem with H' value ≥ 1.5 is regarded as medium to high diverse in terms of species (Kent and Coker, 1992). The obtained results conform to the results reported from homegarden in Kerala India where H' between 1.12 - 3 was obtained (Kumar *et al*., 1994) and lower than 2.53 - 2.73 reported from traditional AF plots in Ethiopia (Molla and Kewessa, 2015). The higher values of diversity indicate greater stability of the community structure (Narayan *et al*., 1994 in Kohli *et al.,* 1996). Usually the Shannon diversity index (*H*') is high when the relative abundance of the different species in the sample is even and is low when few species are more abundant (Molla and Kewessa, 2015). This showed that in the study area, a few species dominated the AF plots. However, Mwangoka *et al.* (2010) indicated that, with proper management, it is possible for the AF system to have diversity close to natural forests.

CONCLUSION AND RECOMMENDATION

There were a number of AF practices in Lushoto district. The types were mainly influenced by farm sizes. The AF plots were composed of few tree species with low basal area per hectare. *Grevillea robusta* was a dominating tree species with the highest Importance Value Index (IVI). The AF plots in the study area had acceptable H'. The results obtained from this study which indicated a relatively stable ecosystem within AF plots is an indication that the AF plots are capable of providing acceptable ecological benefits. It is recommended that the number and species of tree component in AF plots need to be increased in the study area.

REFERENCES

Dawson, I.K., Guariguata, M.R., Loo, J.A. and Guarino, L. 2013. What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. *Biodiversity and Conservation*, 22:301-324.

Hamisy, W.C. and Mathias, S. 2001. Survival and growth of three *Liquidamber styraciflua* provenances at Lushoto, Tanzania. *TAFORI Newsletter*, Vol. 2 No. 1; 7 – 13.

Hoehn, P., Steffan-Dewenter, I. and Tscharntke, T. 2010. Relative contribution of agroforestry, rainforest and open-land to local and regional bee diversity. *Biodiversity Conservation* 19:2189–2200.

Huang, W., Pohjonen, V., Johansson, S., Nashanda, M., Katigula, M.I.L. and Luukkanen, O. 2003. Species diversity, forest structure and species composition in Tanzanian tropical forests. *Forest Ecology and Management* 173: 11 - 24.

Huwe, C and Mwihomeke, S. 1990. Development and Research Activities within the Soil Erosion Control and Agroforestry Project in the West Usambara mountains – Tanzania. paper presented in the Workshop on "participatory Methods for On-farm, Agroforestry Research" ICRAF Nairobi, 19 pp

Islam, M., Dey, A. and Rahman, M. 2015. Effect of Tree Diversity on Soil Organic Carbon Content in the Homegarden Agroforestry System of North-Eastern Bangladesh. *Small-scale Forestry*, Volume 14, Issue 1: 91-101.

Kent, M. and Coker, P. (1992). *Vegetation Description and Analysis, A practical Approach.* Belhaven Press, 25 Floral Street, London. 363pp.

Kihiyo, V.B.M.S. 1985. An economic evaluation of some aspects of the wattle industry in Tanzania. MSc thesis, Sokoine University of Agriculture, Morogoro, Tanzania

Kohli, R. K., Sigh, H. P. and Rani, D. 1996. Status of floor vegetation under some monoculture and mix culture plantations in North India. *Journal of Forest Research* 1: 205 - 209.

Kumar, B. M., George, S.J. and Chinnamani, S. 1994. Diversity, structure and standing stock of wood in the homegardens of Kerala in peninsular India, *Agroforestry Systems*, vol. 25, no. 3: 243–262.

Maro, G., Msanya, B. and Mrema, J. 2014. Soil Fertility Evaluation for Coffee (*Coffea arabica*) in Hai and Lushoto Districts, Northern Tanzania. *International Journal of Plant & Soil Science*, Vol:3(8): 934-947.

Mekonnen, E. L., Asfaw, Z. and Zewude, S. 2014. Plant species diversity of homegarden agroforestry in Jabithenan District, North-Western Ethiopia. *International Journal of Biodiversity and Conservation* Vol. 6(4), 301 - 307.

Molla, A and Kewessa, G. 2015. Woody Species Diversity in Traditional Agroforestry Practices of Dellomenna District, Southeastern Ethiopia: Implication for Maintaining Native Woody Species. *International Journal of Biodiversity* Volume 2015, Article ID 643031, 13 pp.

Mueller-Dombois, D. and Ellenberg, H. 1974. *Aims and methods of vegetation ecology*. Jon Wiley and Sons, New York. 547pp.

Munishi, P.K.T., Philipina, F. and R.P.C. Temu 2006. On-farm Tree Resources and Farmer Motives for on farm Tree Retention and Management in BumbuliWard, Lushoto District North Western Tanzania. In: In: S.A.O Chamshama, L. Nshubemuki, S. Iddi, R.E Swai, M.L. Mhando, E.sabas, C. Balama, L. Mbwambo and M. Mndolwa (Eds). *Proceedings of the Second National Agroforestry and Environment Workshop (Partnerships and Linkages for a Greater Impact in Agroforestry and Environmental Awareness)*, Mkapa Hall, Mbeya Tanzania 14th – 17th March 2006. pp 188 - 198.

Mwangoka, C.M.M.; Mkongewa, V.; Doggart, N. and Vihemaki, H. 2010. Assessment of the biological values of different land cover types in the East Usambara Mountains of Tanzania. TFCG Technical Paper No. 23, DSM, 91pp.

Nair, P.K.R. 1993. *An introduction to Agroforestry*. Kluwer Academic publishers, Dordecht, Pp 500.

Namwata, B.M.L.; Masanyiwa, Z.S. and Mzirai, O.B. 2012. Productivity of the agroforestry systems and its contribution to household income among farmers in Lushoto District, Tanzania. *International Journal of Physics and Social Sciences*, 2(7): 369-292.

Reddy, S.C., Ugle, P., Murthy, R.S.M. and Sudhakar, S. 2008. Quantitative structure and composition of Tropical Forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. *Taiwania*53 (2): 150 - 156.

Scherr, J.S. 1990. Evaluating Farmers' Agroforestry Systems. Paper presented to the DSO Training Course on Agroforestry Research and Development. (unpublished). ICRAF House, Nairobi. Pp 15.

Shrestha, R., Karmacharya, B. S. and Jha, K.P. 2000. Vegetation analysis of natural and degraded forests in Chitrepani in Siwalik region of Central Nepal. *Journal of Tropical Ecology*, 41 (1): 111 - 114.

Wiersum, K.F., Anspach, C.L., Boerboom, J. H.A., Rouw, A. and Veer, C.P. 1995. Development of ecological methods of upland farming in West Usambara Mountains, Tanzania. *FAO Forestry Paper* 5: 55 – 82.UNESCO/FAO. 1977. Soil of the World 1: 5 000 000.00 Vol. VI Africa. FAO Rome.

THE ROLE OF SHADING TREES IN MICRO-CLIMATE AMELIORATION: A CASE STUDY OF SMALLHOLDER FARMS IN MOSHI DISTRICT, TANZANIA

[1]Kajembe, J., [2]Olesen, J.E., [2]Plauborg, F. and [3]Lupala, I.

[1]Tanzania Forestry Research Institute, P.O. Box 1854, Morogoro.

[2] Aarhus University, Department of Agroecology, 8830 Tjele, Denmark

[3]Tanzania Forest Services (TFS) Agency, P.O. Box 404, Same, Kilimanjaro

Correspondence author email: jgkajembe@gmail.com

ABSTRACT

This study assessed the role of shading trees in micro-climate amelioration in Moshi District, Tanzania. Specifically the study aimed at identifying shading tree species commonly used in agroforestry systems in different agroecological zones and to assess and compare the influence of shading tree species on soil and air temperature in different agroecological zones. Two study villages were purposively selected. Data collection methods involved questionnaires, focus group discussions and temperature measurements in farms. A total of 60 farmers were interviewed. Temperature data were collected for shading trees at six farms. Soil temperature was measured at 5 cm soil depth and air temperature at 1.5m height under tree shade and with no tree shade. Data were recorded at 5 minutes interval for 24 hours. *The study found that Albizia schimperiana, Grevillea robusta, Rauvolfia caffra* and *Albizia gummifera* were the common shading tree species. Soil and air temperature differences ranged from -0.3-1.9 ^{0}C and -3.1 -1.5 ^{0}C respectively. Thus there was no significant effects of shading tree species (p >0.05) on either soil or air temperature difference in both highland and midland zones. Lack of significant differences among shade tree species may be credited to cloudy and rain conditions and also the shorter time span for temperature measurements.

Key words: Shading trees; Micro-climate and Amelioration

INTRODUCTION

Climate change has raised concern on the future of food supply, since crop growth could be severely affected by changes in key climatic variables particularly temperature. As temperatures continue to rise due to anthropogenic greenhouse gas emissions, its impacts on agriculture production are expected to become more significant (Doering, 2002). Moreover, it is widely acknowledged that the increasing heat stress caused by increasing temperatures will have larger negative impacts in the tropics than in the temperate latitudes and smallholder farmers are among the most vulnerable to its impacts (Rao *et al*., 2007). Lott *et al*. (2009) suggested the use of trees in smallholder farms to improve micro-climatic conditions. Also Gregory and Ingram (2000) noted that, the presence of trees in agriculture can have beneficial ecological functions on the agro-ecosystem through the mitigation of micro-climatic effects. In addition, Sanchez and Leakey (1997) indicated that, integrating trees with crops (coffee) on the same land is more beneficial as compared to mono-cropping. This is due to the fact that, trees have different impacts on soil properties which is particularly associated with their longer residence time, larger biomass accumulation and more extensive root systems. Thus intervention of trees in smallholder farms have the ability to provide environmental, social and economic benefits and thus making farmers able to address local needs (e.g. food, fodder and firewood) and micro-climate improvements (Rao *et al*., 2007).

Shade tree species form an integral part of the farming system (Regmi, 2003). They provide nutrients for agricultural crops such as coffee. Shade provided by trees also, helps to keep associated crops cooler during the day and warmer at night (Lin, 2007). Moreover, a combination of either indigenous or exotic trees with crops supports nutrition, increase stability of production and improve farmers' income (Steffan *et al*., 2007). Despite the fact that the importance of trees on the farmland are locally, nationally and globally recognized and well acknowledged, the role of shading trees as an important factor in ameliorating microclimate (soil and air temperature) of smallholder farms is not well documented. For instance, a study by FAO (2013) was conducted to reveal the socio-economic aspects of trees in different land use practices while (Namwata *et al*., 2012) analyzed the contribution of different land use practices for livelihood improvements. However, information on the biophysical aspects of trees particularly with regards to the influence of shading trees on microclimate amelioration under coffee crop (e.g. soil and air temperature) were still limited (Lott *et al*., 2009). It should be noted that, different initiatives of incorporating different trees species into national agricultural development programmes in Tanzania have offered more affordable and sustainable sources of soil nutrients through nitrogen fixation by trees and this cultivation method may potentially have modified the microclimatic effects leading to improvement of agricultural productivity (Namwata *et al*., 2012). The main objective of this study was to assess the role of shading trees in ameliorating microclimate in smallholder farms in Moshi District, Tanzania. Specifically the study intended to identify shading tree species commonly used in the study area and to assess and compare the influence of shading tree species in micro-climate amelioration of soil and air temperature.

MATERIAL AND METHODS

Description of the study area

The study was conducted in Moshi District, Tanzania. Moshi District is located in Kilimanjaro region, North Eastern part of Tanzania. It lies between 3°03′ - 3°20′ S and 37°15′- 37°21′ E. The District covers a total area of 171,300 ha. Whereby, arable land covers 124,254 ha, natural forests covers 38,676 ha and the remaining 8370 ha is non-arable land covered by rocks, hills and gullies. The district is administratively divided into 4 divisions, 31 wards, 165 villages and 689 hamlets (URT, 2003). There are two main ethnic groups in Moshi District Chagga and Pare (Soini**,** 2005). In this district, temperature and altitude range are classified according to agro-ecological zones (Table 1).

Table 1: Temperature and altitude data based on agro-ecological zones in Moshi District, Tanzania

Ecological zone	Altitude (m)	Temp (^{o}C)	Main crop	Rainfall (mm)
Highlands	1 500 - 1 800	15-20	Coffee/bananas	1200-2000
Midlands	1 100 - 1 500	20-30	Maize/beans	1000-1200
Lowlands	900-1100	>30	Maize and livestock	400-900

Source: (Zongolo *et al*., 2000; URT, 2003)

Sampling Procedure

The district was stratified into three agro-ecological zones (highland, midland and lowland). The highland and midland zone were purposively selected because the majority of smallholder farmers in these two zones frequently use shading trees in their agricultural field. According to Soini **(**2002**)** the highland and midland zones are more densely populated than most areas with population density of about 650 persons per km^2 compared to lowlands which have approximately 250 persons per km^2**.** This scarcity of land provides an incentive for enhancing productivity, such as through use of agroforestry.

For each of the selected agro-ecological zone, one village was selected, Shimbwe Juu in the highland zone and Mwasi Kusini in the Midland zone. From each study village about 30 representative households (Bailey, 1998) were selected randomly making a total sample size of 60 households. Out of the 60 households selected, three farms were selected randomly in each of the study village and used to collect experimental data.

Data collection

Identification of shading trees in the study area was done by the use of structured questionnaire with both closed and open questions and focus group discussion with the key informants. Sixty interested farmers were interviewed in two of the representative villages. The primary purpose of these interviews was to gather information concerning the history and background of tree species whose function was to provide shade when integrated with agricultural crops and also to provide direction concerning the fundamental issues and questions to be answered experimentally. Measurements of soil and air temperature were carried out to assess the influence of shading trees in ameliorating microclimate. Three farmers from each village with shading tree species integrated with crops in their agricultural land were randomly selected to check the effect of the shade provided by these species on soil and air temperature. Thus, six farms out of 60 farms used for questionnaire survey (three from each village) were selected for temperature measurements. The three farms were represented by three dominant species found in the study area. Each of the selected farms was measured based on a particular species, whereby the first farm *Albizia schimperiana* , second farm *Rauvolfia caffra* and the third farm *Grevillea robusta* species whose effect was measured. The same selection of farms based on dominant species was also conducted in midland zone as one of the selected study area. The reasons for selecting only three farms from each village for experimental study was due to limited time for data collection and weather conditions during the particular period which was dominated by rainfall. Simultaneous measurement of soil and air temperature was carried out in a one day campaign at six of the selected sites, each site on a different day as resources allowed only one set of equipment. The temperature sensors were placed at different positions in the specified plots based on the distance and species canopy.

Soil temperature was measured by using three soil temperature sensors (Em50 from DECAGON DEVICES COMPANY). The temperature sensors were located at different distance. Soil temperature were taken at the soil depth of 5 cm in a plot with a size of 5m x 5m; at three different positions of tree influences; Full shade (under the crown), Semi-shade (at the edge of tree crown) and Full sun (open field) as suggested by (Wilson *et al*., 1997) . Data recorded by dedicated logger (Em50 series data loggers from DECAGON DEVICES COMPANY) which has a protected memory section. The recording was done at 5 minutes interval for a period of 24 hours. Further, the two air temperature sensors were placed at two points. The first on a wooden stick about 1.5m above the ground on the full shade and the second was inserted by using the same procedure but in no shade (Shashua and Hoffman, 2000). Hence air temperature was measured at two different locations both protected from strong winds but good openness to air circulation. To prevent the air temperature sensors from direct solar radiation or other influences, a radiation shield was used to shield the sensors.

Data analysis

The responses to the questionnaires for the household survey were analyzed by using Statistical Package for Social Science (SPSS) version 15 software. Average hourly soil and air temperature were calculated in open and under shade for all three species found on the Highland and Midland zone. Then the average diurnal temperature range for soil and air were calculated based on the average maximum temperature and minimum temperature for both open and under shade of different tree species. Thus based on the calculated hourly reading at each sample point, the average temperature difference (open area minus shade) for soil and air at each specific time category were calculated. In other words, for each measurement made under a tree shade, there was a corresponding observation made at the open area. The difference between the two corresponding measurements taken simultaneously at two sites (open and under shade) was considered to be partly attributable to the shade tree. Thus the differences in temperature obtained for soil and air were analyzed in a statistical model presented in the next sections to assess the effect of shading on soil and air temperature.

Two different models, Linear and Linear mixed models were used to analyze the effect of shading on soil and air temperature. The first model included all the treatment effects (Species, Area and Time as fixed effects) and the second model included both fixed and random effects. The fixed effects were indicated by time and species for each area were taken as random effects. The main reason of using two models was to compare the two models to see which one was able to describe the effect of shading on soil and air temperature data. The response variables were the differences in soil and air temperature and treatments effects were the species (*Albizia schimperiana*, *Rauvolfia caffra* and *Grevillea robusta*), Area (Highland and Midland zone) and Time of the day. However, the time of the day were classified into four categories for each species i.e. Morning (6:00 – 11:59), Midday (12:00 – 17:59), Afternoon (18:00 – 23:59) and Night time (00:00 – 5:59).

Models used to find the effect of shading on soil and air temperature were as follows:

Model1: $T_{diffij}=\mu + \alpha_h + \beta_A + T_S + Eij;$

Where, T_{diffij} = response variable (soil and air temperature difference), μ= mean, α_h =Time of the day, T_S = Tree species (*Albizia schimperiana, Rauvolfia caffra, Grevillea robusta*) β_A = Area (Highland and Midland zone), Eij=random error

Model 2: $T_{diffij}=\mu + \alpha_h + \beta_{1|unit} + Eij$;

Where, T_{diffij}= Response variable (soil and air temperature) μ= Estimated mean, α_h= Fixed term for time of the day, $\beta_{1|unit}$ = Random effect for species (*Albizia schimperiana, Rauvolfia caffra, Grevillea robusta*) at each area Eij= Random error

In order to check if the selected model adequately described the data, residuals for the model were assessed which indicated no systematic variation of residuals. The analysis of variance (ANOVA) and coefficient tables were calculated for each model. The ANOVA tables derived from models of similar components were used to estimate the effect of time during the day, species and area as treatment effects on the response variables (soil temperature difference and air temperature difference). The coefficient tables were calculated mainly to draw comparisons between treatment effects. The treatments were judged to be significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Table 2 shows the dominant shading tree species integrated with coffee in the study area. It was noted that, *Albizia schimperiana, Grevillea robusta and Rauvolfia caffra* were preferred by the farmers as shading trees for *Coffea Arabica* crop.

Table 2: Response of farmers for the dominant shading tree species integrated with coffee in, Moshi District, Tanzania.

Shading tree species	% of farmers response
Albizia schimperiana	35
Grevillea robusta	48
Rauvolfia caffra	*17*
Total	100

The reasons for the selection of tree species by the farmers were due to the contribution of those three species to the daily life of the surrounding communities. Akbari and Taha (1992) revealed the importance of trees incorporated with different crops in the agricultural land as having a huge positive effect on people's lives including amelioration of microclimate. However, the choice of tree to be used in the farming system is a key step for the success of this practice. Selection of the tree species must be made based on the objective of the system, the site conditions i.e. soil and climate and the species adaptability to the region. Aiming at protecting coffee from hazardous environmental impacts, it was noted by Caramori *et al*. (2004) that, some of the mentioned species such as *Gravillea robusta* has been used in different parts of the world for instance in Brazil which was proven to have the satisfactory results. Most of the tree attributes considered favourable as shade trees by farmers in the study area are similar to what has been reported for Costa Rica (Albertin and Nair, 2004).

The influence of shading tree species in micro-climate amelioration

Diurnal temperature variation and diurnal range of soil and air temperature

Table 3 summarizes the average differences of air and soil temperature (Topen-Tshade) for three dominant tree species found in Moshi District. There was very little effect of shading on soil and air temperature for both highland and midland zones. In few cases there were higher soil and air temperature of about 1^0C in the open than under shade during the day. There was one case observed under *Albizia schimperiana* in the midland zone, where the air temperature increased under shade in the afternoon.

Table 3: Average differences of air and soil temperature (Topen-Tshade) for three dominant tree species found on the study area

Area	**Tree Species**	**Time (hours)**	**Soil temp difference (Topen-Tshade) ^{0}C**	**Air temp difference (Topen-Tshade) ^{0}C**
Highland	*Albizia schimperiana*	6:00 – 11:59	-0.2	-0.2
Highland	*Albizia schimperiana*	12:00 – 17:59	0.0	-0.2
Highland	*Albizia schimperiana*	18:00 – 23:59	0.5	0.2
Highland	*Albizia schimperiana*	00:00 – 5:59	0.0	-0.3
Highland	*Rauvolfia caffra*	6:00 – 11: 59	0.4	-0.1
Highland	*Rauvolfia caffra*	12:00 – 17:59	0.4	0.3
Highland	*Rauvolfia caffra*	18:00 – 23:59	0.4	0.8
Highland	*Rauvolfia caffra*	00:00 – 5:59	0.4	-0.1
Highland	*Grevillea robusta*	6:00 – 11:59	0.1	-0.1
Highland	*Grevillea robusta*	12:00 – 17:59	0.0	-0.1
Highland	*Grevillea robusta*	18:00 – 23:59	-0.2	0.0
Highland	*Grevillea robusta*	00:00 – 5:59	-0.1	0.1
Midland	*Albizia schimperiana*	6:00 – 11:00	-0.3	0.8
Midland	*Albizia schimperiana*	12:00 – 17:59	0.4	1.5
Midland	*Albizia schimperiana*	18:00 – 23:59	0.1	-3.1
Midland	*Albizia schimperiana*	00:00 – 5:59	-0.2	-1.9
Midland	*Rauvolfia caffra*	6:00 – 11:59	0.1	-0.1
Midland	*Rauvolfia caffra*	12:00 – 17:59	0.0	-0.1
Midland	*Rauvolfia caffra*	18:00 – 23:59	-0.2	0.0
Midland	*Rauvolfia caffra*	00:00 – 5:59	-0.1	0.1
Midland	*Grevillea robusta*	6:00 – 11:59	1.0	1.4
Midland	*Grevillea robusta*	12:00 – 17:59	1.9	1.3
Midland	*Grevillea robusta*	18:00 – 23:59	1.1	0.5
Midland	*Grevillea robusta*	00:00 – 5:59	0.0	-0.2
		Maximum	1.9	1.5
		Minimum	-0.3	-3.1

On the other hand, diurnal temperature range, calculated from T=Tmax-Tmin in the open or under shade for *Albizia schimperiana*, *Rauvolfia caffra* and *Grevillea robusta* found on the Midland and Highland zone is presented in Figure 1a and 1b. The diurnal temperature range varies roughly by 1-7 °C at 5cm depth for soil temperature and 4-9 °C in air temperature for all the three species found on both Highland and Midland zone. The soil temperature range was higher in the Midland than in the Highland. On the contrary, the air temperature range indicated some variations in both highland and midland. Air temperature range was slightly higher in the open area for the highland zone when compared to Midland.

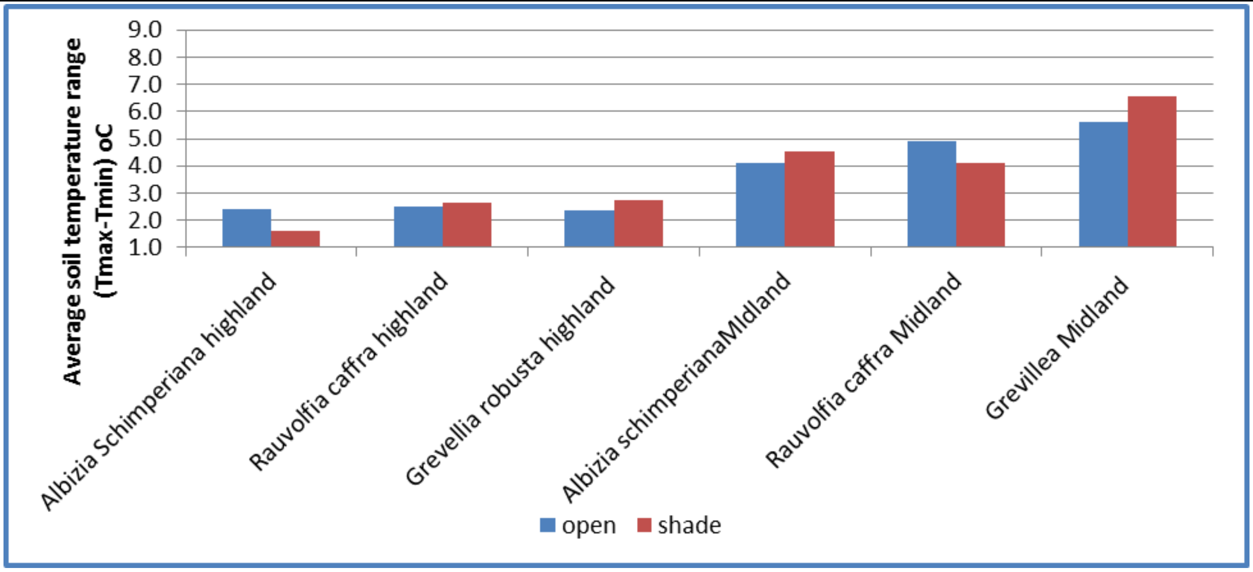

Figure 1a. Average diurnal soil temperature range calculated from T=Tmax-Tmin in the open or under shade for *Albizia schimperiana*, *Rauvolfia caffra* and *Grevillea robusta* found on the Midland and Highland zone.

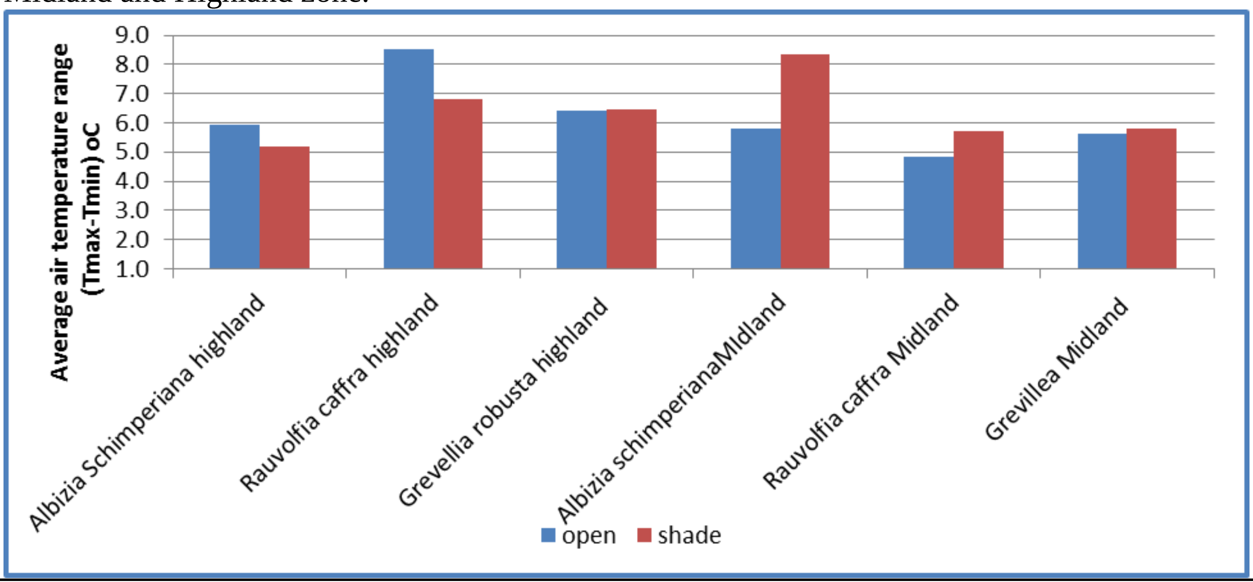

Figure 1b: Average diurnal air temperature range, calculated from T=Tmax-Tmin in the open or under shade for *Albizia schimperiana*, *Rauvolfia caffra* and *Grevillea robusta* found on the Midland and Highland zone.

Daily mean temperature is generally used as universal indicator in climate change studies. However it has been found by several researchers that mean temperature alone is not enough to reflect the complicated variation of climate, and (Moot *et al*., 1996; Sun *et al*., 2006) indicated that the trends which are observed in mean surface temperature are often due to changes that takes place in daily maximum and minimum temperature. Therefore this shows that diurnal temperature range (Tmax-Tmin) is also an important factor in climate change studies (Karl *et al*., 2004; Qu *et al*., 2014). In our case the low diurnal temperature range was caused by cloudy conditions (Karl *et al*., 1987; Qu *et al*., 2014). On the cloudy days, the ground is shielded from the incoming solar radiation because of reflection and absorption of radiation. Hence this will lead in reduction of the amount of solar radiation reaching the surface and cause cooling at the surface. Thus, with less incoming solar radiation during day time and less radiative cooling during night, it means it lead into lower diurnal temperature variation compared to clear sky. On cloudy nights the heat loss from the ground is also decreased.

Furthermore the changes in canopy cover due to different tree management practice such as pruning could probably contribute to variation in microclimatic conditions. Winds, especially at night, reduce the cooling of surface air by bringing down and mixing warmer air from above. For instance, the decline in temperature moderation in some of the shading tree species as indicated in Table 3 with time relative to the shade effect might be due to increasing tree height and removal of branches which increases the distances between the tree canopy and the ground and thus would probably influence the air flow. However there are some of microclimatic variables which are indeed highly sensitive to changes in the over story canopy structure and air temperature is one of them (Saunders *et al*., 1999). Additionally, Saunders *et al*. (1999) indicated that, by considering the influence of tree shape (Dbh) and tree height, the dense canopy which has lower average tree height tends to perform better in terms of the cooling effect. This may result from higher humidity. In the present study *Gravillea robusta* with the soil temperature difference of 1.9 ^{o}C and air temperature difference of 1.3^{o}C in the midland zone has shown a slightly higher cooling effect compared to the two other species, which may be attributed to tree height since *Grevillea robusta* had the lowest average tree height 12m while *Rauvofia* has the average tree height of 18m and *Albizia* had the highest tree height of 23m. Saunders *et al*. (1999) indicated that, the tree types such as upright or spreading, large or small might also affect tree shade effects. However, it was indicated by Sandor and Fodor (2012), that, the main driving forces determining the soil temperature are air temperature and solar radiation possibly linked to other factors such as soil moisture, precipitation and surface cover (plant canopy and crop residue). Generally, shading causes some temperature variations under the smallholder farms; however, these effects were not significant in our study were probably due to rainy conditions. Other studies have observed the shading effect to be significant when measurements were taken during midday with hot sunny days. For instance, Lin and Lin (2010) observed that, in a coffee plantation under the shade of *Inga jinicuil*, the average maximum temperature was 5.4^{0}C lower and the minimum temperature 1.5^{0} C higher.

Effect of shading on soil and air temperature in the study area

Performance of dominant tree species, location and time on regulation of soil and air temperature levels is presented in Table 4. The results indicated that, there was no significant effect of air and soil temperature among tree species, location and time in the study area (p-values> 0.05).

Table 4: Performance of dominant tree species, location and time on regulation of soil and air temperature levels

Temperature	Treatment effects	F-value	Pr(>F)
Soil Temperature	Tree species	1.16	0.23
	Time(hrs)	0.84	0.49
	Location(Highland and midland zone)	0.73	0.41
Air Temperature	Tree species	1.30	0.30
	Time(hrs)	1.08	0.38
	Location(Highland and midland zone)	0.00	0.98

Significance levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Shade is one of the most recognizable characteristics of any tree. On hot sunny days, the outline or effect of a shady area is probably more noticed than the tree itself. The use of these trees minimizes the exposition of plants to climatic risks such as high temperature which could probably result to sustainability of the associated crops such as coffee in the agroforestry systems (Sun *et al*., 2006). According to Simpson (2002) the effect of shading trees on soil and air temperature is an important parameter for the agroforestry systems; this is due to the fact that, moderate temperature underneath tree crowns may increase biomass of below species and reduce water and heat stress. Although there were not statistically significant effects of the shading trees in this study on the cooling of soil and air temperature, the soil and air temperature under the shade tree canopies were slightly lower, probably due to the shade effect. Lin and Lin (2010) indicated that, the significant cooling effect of the shade trees is found on sunny days in hot seasons in the tropics and subtropics. Thus during the experiment, the microclimatic conditions under the tree canopies and unshaded open space were measured repeatedly during the mid days without precipitation .This would probably explain why we did not get significant effect of shading trees on soil and air temperature in our study. Thus the lack of significant differences among shade treatments may be credited to the weather conditions during the time when the experiment was conducted which has substantially reduced the shade effect. Lin and Lin (2010) noted that, wind speed and vapour pressure were indicated to have negative effects in his experiment. Thus he concluded that, the cooling effect of shade tree depends very much on the weather at the time of experiment. Simpson (2002) indicated that, there are other tree characteristics that might affect the tree shade effects e.g. specie morphology, canopy cover and leaf area.

CONCLUSION AND RECOMMENDATION

The common shading tree species in the study area are *Albizia schimperiana*, *Grevillea robusta*, *Rauvolfia caffra* and *Albizia gummifera.* The identified shading tree species did not significantly affect soil and air temperature in the midland zone as well as in the highland zone during the measurement period. Other treatment effects such as time and location did not show statistical significance effect on either soil or air temperature difference. Weather conditions (cloudy and rains) and lack of replication during the time of experiment probably explain why the shading effect on soil and air temperature was non-significant. In order to be able to observe significant effect of shading trees in microclimate amelioration, the temperature measurements should probably be taken in a larger time span and not just few days during a period of the season.

REFERENCES

Akbari, H. and Taha, H., 1992. The impact of trees and white surfaces on residential heating and cooling energy use in four Canadian cities. *Energy* 17 (2):141–149.

Albertin, A. and Nair, P. K. R. 2004. Farmers' Perspectives on the Role of Shade Trees in Coffee Production Systems: An Assessment from the Nicoya Peninsula, Costa Rica. Human Ecology, 32:4.

Bailey, K. D. 1998. Methods of Social Research. The free Press. A division of Macmillan Inc., New York. 88pp.

Caramori, P.H.; Kathounian, C.A.; Morais, H.; Leal, A.C.; Gorreta, R.; Rocioli filho, A. Arborização de cafezais e aspectos climatológicos. In: MATSUMOTO, S.N. (Org.). Arborização de cafezais no Brasil. Vitória da Conquista: Edições Uesb, 2004. p. 21-38

Doering, O.C**.,** Randolph**,** J.C**.,** Southworth**,** J., and Pfeifer, R.A. 2002. *Effects of Climate Change and Variability on Agricultural Production Systems*. Kluwer Academic Publishers, Dordrecht, Netherlands.

FAO 2013. Agroforestry, Food security and climate change. Summary of learning event [http/www.fao.org/climate change/36562-0ce6bd83e1316de8db1bf4efbf2fed53a.pdf].site visited on 20/ august/2013.

Gregory, P.J., Ingram, J.S.I., 2000. Global change and food and forest production: future scientific challenges. Agric. *Ecosystem Environment*, 82:3–14.

Karl, B., Karoly, D.J., Arblaster, J.M., 2004. Diurnal temperature range as an index of global climate change during the twentieth century. *Geophysics Resource*, 31:17.

Karl, T.R., Kukla, G., Gavin, J. 1987. Recent temperature changes during overcast and clear skies on the United States. *Journal of Climatology Applied Meteorology*, 26:698–711.

Lin, B.B. 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric. For. Met. 144, 85–94.

Lin, B.S. and Lin, Y.J. 2010. Cooling Effect of Shade Trees with Different Characteristics in a Subtropical Urban Park. *Hort Science* 45(1):83–86. 2010.

Lott, J.E, Ong C.K. and Black C.R. 2009. Understory microclimate and crop performance in a *Grevillea robusta*-based agroforestry system in semi-arid Kenya. *Agricultural and Forest Meteorology*, 149: 1140–1151.

Moot, D. J., Henderson, A. L., Porter, J. P., and Semenov, M. A. 1996.Temperature, CO2 and the growth and development of wheat: changes in the mean and variability of growing conditions. *Climate Change*, 33:351 -368.

Namwata , M.L.B, Masanyiwa, S.Z. and Mzirai, B.O. 2012.Contribution to Household Income among Farmers in Lushoto District, Tanzania.

Qu, M., Wan, J., and Hao, X. 2014. *Analysis of diurnal air temperature range change in the continental United States*. Weather and Climate Extremes (Article in press).

Rao, K.P.C., Verchot, V.L. and Laarman, J. 2007. Adaptation to Climate Change through Sustainable Management and Development of Agroforestry Systems. World Agroforestry Center, Nairobi, Kenya. An Open Access Journal published by ICRISAT.

Regmi, N.B. 2003.Contribution of agroforestry for rural livelihoods: A case of Dhading District, Nepal. Paper presented at The International Conference on Rural Livelihoods, Forests and Biodiversity19-23 May 2003, Bonn, Germany.

Sanchez, P. A. and Leakey, R. R. B. 1997. Land-use trans- formation in Africa: Three determinants for balancing food security with natural resource conservation. Fourth Congress European Society of Agronomy (In the press).

Sandor, R. and Fodor, N. 2012. Simulation of Soil Temperature Dynamics with Models Using Different Concepts. The Scientific World Journal Volume 2012, Article ID 590287, 8 pages doi:10.1100/2012/590287.

Saunders, S. C., Chen, J. T., Drummer, D., Crow, T. R., 1999. Modelling temperature gradients across edges over time in a managed landscape. *Forest Ecology and Management*, 117:17 – 31.

Sun, D., Pinker, R., Kafatos, M. 2006. Diurnal temperature range over the United States: a satellite view. *Geophysics Resource*, 33.

Shashua-Bar L and Hoffman, M.E. 2000. Vegetation as a climatic component in the design of an urban street: An empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings*. 31(3): 221 - 235.

Simpson, J.R. 2002.Improved estimates of tree shade effects on residential energy use. *Energy Building,* 34:1067–1076.

Soini, E. 2002. Changing Landscapes on the Southern Slopes of Mount Kilimanjaro, Tanzania:

Soini, E. 2005 Changing livelihoods on the slopes of Mt. Kilimanjaro, Tanzania: Challenges and opportunities in the Chagga home garden system. *Agroforestry Systems* 64:157–167.

Steffan-Dewenter, I., Kessler, M., Barkmann, J., Bos, M.M., Buchori, D. and Erasmi, S. 2007 Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. Proceedings of the National Academy of Sciences of the USA, 104: 4973–4978.

United Republic of Tanzania (URT) 2003. *The 2002 Population and Housing Census*, Central Census Office, National Bureau of Statistics, President's Office, Planning and Privatization, Dar-es-salaam. [http://www.Tanzania.go.tz/census/regions.tm] site visited on 16/3/2012.

Wilson, T. D., Brook, R. M. and Tomlinson, H.F. 1997. Interactions between NERE (PARKIA BIGLOBOSA) and Under-Planted Sorghum in a Parkland System n BURKINA FASO *Agriculture*, 34:85 - 99.

Zongolo, S. A., Kiluvia, S. and Mghase, G. 2000. UmbweOnana PRA report. Traditional Irrigation and Environmental Development Organization, Moshi.

OVERVIEW OF THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN FOREST MANAGEMENT: A CASE STUDY OF TANZANIA

Uisso, A.J., Ernest, S. and Balama, C.
Tanzania Forestry Research Institute
P. O. Box 1854, Morogoro, Tanzania
E-mail of corresponding author: *siwa.ernest@tafori.or.tz*

ABSTRACT
Tanzania has about 48.1 million ha of forest area which constitutes 55% of the total land area of Tanzania mainland. Forest resources are managed sustainably by the forest sector to enhance the contribution of the sector to the sustainable development of Tanzania and the conservation and management of her natural resources for the benefit of present and future generations. Geographic Information System (GIS) has been used in forest management in mapping and monitoring of forest resources and has been proved to aid in decision making, to improve productivity and save time, money and manpower. The aim of this paper is to explore the application of GIS for sustainable management of forests and woodlands in Tanzania. The study utilized a desk-top review approach which involved collection of various books, journals, newsletters, reports and working papers integrated with field experiences. It was revealed that, the use of GIS technology in forest management in Tanzania has increased largely from the year 2000. The use of GIS has been in Land Use and Land Cover studies (92%), wildfires analysis (5%) and participatory mapping (3%). Recommendations on the use of this technology in forest management are presented.

Keywords: Geographical Information System; Application; Management; Forestry

INTRODUCTION

Tanzania has about 48.1 million ha of forest area which constitutes 55% of the total land area of Tanzania mainland (TFS, 2015). Out of this total forest area, woodlands occupy 92% and the rest is occupied by humid Montane, lowland, mangrove and plantation forests. This huge forest resources offer habitat for wildlife, beekeeping, unique natural ecosystems and genetic resources; and is an economic base for country development (MNRT, 1998). Forest assessments (inventories) in Tanzania have been carried out since 1971-1973 (TFS, 2015) and mapping of vegetation types have been conducted for more than 100 years (Willcock, 2012). Forest mapping in Tanzania until 1989 used manual drafting which was basically analogy data processing. Data were mainly obtained from traverse forest surveys and manual interpretation of aerial photographs. In recent years, monitoring and mapping of forest resources have advanced as a result of advancement in information technologies. Geographic Information System (GIS) has been used in mapping and monitoring of forest resources and has been proved to aid in better decision making, to improve productivity and save time, money and manpower.

Geographical Information Systems (GIS) also known as Geo Information Sciences (or Geosciences) or Geospatial Information System is a computer based system that capture, prepare, manage (storage and maintenance), manipulate, analyze and present geo-referenced data (Huisman and de By, 2009). Based on this definition, GIS users expect support from the system to enter (geo-referenced) data, analyze it in various ways and to produce presentations (Including maps and other types) from the data. GIS data inputs include vector data e.g. GPS coordinates and raster data e.g. aerial photograph and satellite image. Compared to manual drafting, GIS has efficient handling of large data and efficient spatial analysis capabilities. The GIS technology is used in almost every field including health; soil science; management of agricultural, forest and water resources; business and marketing; urban planning; geology; mineral exploration; cadastre and environmental monitoring. This paper intends to explore the application of GIS technology in forest management in Tanzania.

Forest assessment and mapping in a changing technological environment

Forest mapping in Tanzania can be group in two categories; manual drafting (Mapping initiatives of 1891, 1908, 1923 and 1949) and digital data processing (GIS) (Mapping initiatives of 1989, 1995 and 2014) which started concurrently with satellite remote sensing. Satellite remote sensing is the use of satellite borne sensors to observe, measure and record the electromagnetic radiation reflected or emitted by the earth and its environment for successive analysis and extraction of information. In 1989, Millington and Townsend developed a vegetation map of Southern African Development Coordination Conference (SADCC) (including Tanzania) from the interpretation of Advanced Very High Resolution Radiometer (AVHRR) images onboard NOAA satellite. In 1995, Hunting Technical Services of the United Kingdom and Africover project of the United Nations, each developed a land cover map product from the interpretation of Landsat and SPOT images for Tanzania and the entire African continent respectively. In 2014 National Forest Resources Monitoring and Assessment (NAFORMA) project developed Tanzania land cover map from the interpretation of Landsat images. In these digital mapping initiatives, GIS was used in interpretation of land cover classes from the satellite images. Moreover, the use of GIS has enabled the integration of huge amount of data during mapping (Including forest inventory data), the update of forest cover maps on a constant basis, and has enhanced the access of forest cover maps and mapping activities at local level.

In forest inventory, recently researches have revealed the use of auxiliary remotely sensed data (Interferometric Synthetic Aparture Radar (InSAR) and Airborne Laser Scanning (ALS)) increase precision in biomass estimation in Tanzanian rainforest (Hansen *et al.*, 2015) and woodland (Solberg *et al.*, 2015). The use of these data also provides advantage of lowering inventory cost and has higher areal capacity. Based on the results, InSAR and ALS are expected to provide new possibilities for forest inventory in Tanzania.

GIS in the Forest Management in Tanzania

The review revealed that the use of GIS has increased largely from the year 2000 in forest management. This could be due to declining cost of computer hardware and GIS software, user friendliness of GIS software and increasing awareness as GIS is mostly technological driven. The use of GIS in Forest Management in Tanzania has been in Land Use and Land Cover study (92%), wildfires analysis (5%) and participatory mapping (3%) (Table 1). The 92% indicates the importance of GIS combined with satellite remote sensing in monitoring land cover changes in Tanzania. In all these identified GIS uses in Forest Management in Tanzania (Table 1), GIS has generated critical information that guide decision makers on how to protect and value forest resources.

Table 1: Applications of GIS in Forest Management in Tanzania

Applications in Forest Management	Authors	Title	The use of GIS
Land Use Land Cover study	Prins and Kikula (1996)	Deforestation and regrowth phenology in miombo woodland-assessed by Landsat Multispectral Scanner System data	To assess woodland cover changes from the analysis of Landsat images
	Pelkey *et al* (2000)	Vegetation in Tanzania: assessing long term trends and effects of protection using satellite imagery	To examine changes in vegetative cover across Tanzania using normalized difference vegetation index (NDVI) products derived from imagery taken by Advanced Very High Resolution Radiometer (AVHRR) on board NOAA satellite.
	Wang *et al* (2003)	Remote Sensing of Mangrove Change along the Tanzania Coast	To estimate mangrove areas and mangrove area change from the Landsat images
	FBD (2006)	Forest area baseline for the Eastern Arc Mountains	To map land covers. Also, to quantify and locate degradation of forests and woodlands.
	Mbilinyi *et al* (2007)	Land cover dynamics as a result of charcoal production: use of remote sensing and GIS	To quantify and locate degradation and regeneration of woodlands in assessment of the extent of environmental degradation due to charcoal production
	Nduwamungu *et al* (2008)	Recent land cover and use changes in Miombo woodlands of eastern Tanzania	To generate knowledge on dynamics of land cover and land use in miombo woodlands of eastern Tanzania from the analysis of Landsat satellite images.
	Hall *et al* (2009)	Conservation implications of deforestation across an elevational gradient in the Eastern Arc Mountains, Tanzania.	To develop datasets of forest extent and to estimate area of forest loss between years for the entire Eastern Arc Region, within each mountain block and within elevation bands
	FBD (2010)	Assessment of Forest Area Changes (2000-2007/8) for the Eastern Arc Mountains	To map land covers and monitor changes in the Eastern Arc Mountains
	Platz *et al.* (2011)	Delimiting tropical mountain ecoregions for conservation	To derive terrain parameters, estimate forest cover, overlay derived terrain parameters with forest cover classes and point distribution of vascular plants

		strictly endemic to Eastern Arc Mountains, bounding a chosen regional typology, overlay ecoregion boundaries with forest distributions and protection status; and derive population surface
Tabor *et al* (2010)	Forest and Woodland Cover and Change in Coastal Tanzania and Kenya, 1990 to 2000	To estimate forest and woodland cover and change from satellite imageries, supplemented data from aerial overflights, field surveys and local knowledge
Godoy *et al* (2011)	Deforestation and CO2 Emissions in Coastal Tanzania from 1990 to 2007	To estimate cover and carbon stock of Tanzania coastal forests, as well as CO_2 emissions due to forest loss
Swetnam *et al.* (2011)	Mapping socio-economic scenarios of land cover change: A GIS method to enable ecosystem service modelling	To interpret qualitatively expressed socio-economic scenarios in quantitative maps for use in ecosystem service modelling and valuation
Pfeifer *et al.* (2012)	Land use change and carbon fluxes in East Africa quantified using earth observation data and field measurements	To analyze trends in vegetation cover (biomes) and carbon in East Africa (Including Tanzania), to determine the relationship between fire and vegetation cover, to link fire occurrence and vegetation cover with precipitation; and to assess vegetation cover trend, vegetation burning, and their link to precipitation per land management scheme
Mdemu *et al.,* (2012)	Dynamics of land use and land cover changes in the Pugu and Kazimzumbwi Forest Reserves.	To quantify land use and cover changes from the Landsat images in order to investigate long-term changes that have occurred as a result of human activities
Kimaro and Lulandala (2013)	Forest Cover and Land Use Change in Ngumburuni Forest Reserve, Rufiji District, Tanzania	To determine the status of forest vegetation cover under the influence of land use intensification in the adjacent villages from Landsat satellite images.
Kashaigili *et al* (2013)	Integrated Assessment of Forest Cover Change and Above-Ground Carbon Stock in Pugu and Kazimzumbwi Forest Reserves, Tanzania	To estimate the forest cover change and map tree above-ground carbon stock from the Landsat satellite images and mapping tree above- ground carbon stock
Kashindye *et al,* (2013)	Multi-temporal assessment of forest	To assess forest cover dynamics from the

	cover, stocking parameters and above-ground tree biomass dynamics in Miombo Woodlands of Tanzania	classification of Landsat images, and computation of vegetation indices (VIs) for development of regression equation in predicting Total Above Ground Tree Biomass.
Masanja (2013)	Population dynamics and the contraction of the Miombo Woodland Ecozone: A case study of Sikonge District, Tabora Region, Tanzania	To quantify different cover types and their changes from the analysis of Landsat images
Nzunda *et al.* (2013)	Land use and vegetation cover dynamics in and around Kagoma Forest Reserve in Tanzania	To investigate land use and vegetation cover changes from Landsat images
Willcock *et al.* (2014)	Quantifying and understanding carbon storage and sequestration within the Eastern Arc Mountains of Tanzania, a tropical biodiversity hotspot	To map carbon stored across the watershed of the Eastern Arc Mountains
Kukkonen and Kayhko (2014)	Spatio-temporal analysis of forest changes in contrasting land use regimes of Zanzibar, Tanzania	To estimate forest changes and deforestation trends within forest land use regimes on the island of Unguja (Zanzibar) from the satellite images.
Lupala *et al.* (2014)	Effects of Peri-Urban Land Use Changes on Forest Ecosystem Services: The Case of Settlements Surrounding Pugu and Kazimzumbwi Forest Reserves in Tanzania.	To estimate land use area and land use changes from aerial photographs in assessing effects of peri-urban land use changes on forest ecosystem services
Mongo *et al.* (2014)	Forest cover changes, stocking and removals under different decentralized forest management regimes in Tanzania	To estimate forest cover changes from Landsat imageries in providing insights on the influence of decentralized approaches to forest resources conditions.
Soka and Nzunda (2014)	Application of Remote Sensing and developed allometric models for estimating wood carbon stocks in a North – Western Miombo woodland Landscape of Tanzania.	To analyze land use and land cover changes from Landsat imagery in estimating the amount of wood carbon which is stored and lost.
Lupala *et al.* (2015)	The land use and cover change in Miombo woodlands under Community Based	To develop land cover maps for exploring the dynamic of land use and covers change and biomass

	Forest Management and its implication to Climate Change mitigation: A case of Southern Highlands of Tanzania	due to Community Based Forest Management (CBFM).
Ojoyi *et al.* (2015)	An analysis of ecosystem vulnerability and management interventions in the Morogoro region landscapes, Tanzania	To estimate annual rate of forest changes from the Landsat images in assessing vulnerability status of natural forests in Morogoro.
Mganga and Lyaruu (2015)	Applicability of Satellite Remote Sensing in accounting above-ground carbon in Miombo Woodlands	To compute Normalized Vegetation Index (NDVI) from Landsat images to investigate the effectiveness of remote sensing in estimating the carbon stock in Miombo woodlands.
Ndumbaro (2015)	Understanding Spatial Flow of Building Poles' Opportunities and Challenges for Sustainable Livelihoods and Forest Resources: The Case of Zanzibar, Tanzania	To overlay GPS points of building poles depots over the land use maps
TFS (2015)	Main result: National Forest Resources Monitoring and Assessment of Tanzania Mainland	To produce Land Use Land Cover map of Tanzania mainland from satellite imagery.
Mayes *et al*. (2015)	Forest cover change in Miombo Woodlands: modeling land cover of African dry tropical forests with linear spectral mixture analysis	To assess land cover dynamics and forest changes in Tanzania Miombo woodland landscape from Landsat images. Ancillary data used were MODIS and Quickbird images.
Jew *et al*. (2016)	Miombo woodland under threat: Consequences for tree diversity and carbon storage	To categorize land use from Landsat images
Tabor *et al*. (2016)	Forest Cover and Change for the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya circa 2000 to circa 2010	To update and validate the land over maps for the Eastern Arc Mountains and Coastal Forests of Tanzania.
Gizachew *et al.* (2016)	Mapping and estimating the total living biomass and carbon in low-biomass woodlands using Landsat 8 CDR data	To extract spectral reflectance values from the pixel containing NAFORMA plots center and to calculate spectral indices from different spectral band

			combinations.
	Makero and Kashaigili (2016)	Analysis of land cover changes and anthropogenic activities in Itigi thicket, Tanzania	To assess land cover changes of Itigi thicket from Landsat images.
Wildfires analysis	FAO (2013)	A fire baseline for Tanzania	To estimate the spatial distribution and size of wildfires in Tanzania from MODIS active fire &burned area product.
	Tarimo *et al.* (2015)	Spatial distribution of temporal dynamics in anthropogenic fires in miombo savanna woodlands of Tanzania	To analyze MODIS active fire product and Landsat satellite images in assessment of spatio-temporal distribution of fires in miombo woodlands of Tanzania
Participatory mapping	Duvail *et al*. (2006)	Participatory mapping for local management of natural resources in villages of the Rufiji District (Tanzania)	To produce georeferenced village land use maps (with emphasis on official recognition of Village Forest Reserves).

CONCLUSION AND RECOMMENDATION

The use of Geographical Information System provides necessary information for decision making on the management of forest resources in Tanzania. There is a rapidly increase in the use of GIS in forest management from the year 2000, and the use is mostly in Land Use Land Cover study. Other uses are in wildfire monitoring and participatory mapping. The increasing trend towards the use of GIS in forest indicates that greater diversity can be expected in future.

REFERENCES

Duvail, S., Hamerlynck, O., Nandi, R.X.L., Mwambeso, P., Elibariki, R. 2006. Participatory mapping for local management of natural resources in villages of the Rufiji District (Tanzania). The Electronic Journal on Information Systems in Developing Countries, 25, 6, 1 - 6

FAO 2013. A fire baseline for Tanzania. Sustainable Forest Management in a Changing Climate. Dar Es Salaam 75pp.

Forestry and Beekeeping Division. 2006. Forest Area Baseline for the Eastern Arc Mountains. Compiled by Mbilinyi, B.P., R.E. Malimbwi, D.T.K. Shemwetta, Songorwa, E. Zahabu, J.Z. Katani and J. Kashaigili for Conservation and Management of the Eastern Arc Mountain Forests, Forestry and Beekeeping Division, Dar es Salaam.

Forestry and Beekeeping Division. 2010. Assessment of Forest Area Changes (2000-2007/8) for the Eastern Arc Mountains. Forestry and Beekeeping Division, Dar es Salaam.

Gizachew, B., Solberg, S., Naesset, E., Gobbaken, T., Bollandsas, OM., Breidenbach, J., Zahabu, E., Mauya, E.W. 2016. Mapping and estimating the total living biomass and carbon in low-biomass woodlands using Landsat 8 CDR data. Carbon Balances and Management 11:13. DOI 10. 1186/S13021-016-0055-8.

Godoy, F.L., Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., Steininger, M.K. 2011. Deforestation and CO2 Emissions in Coastal Tanzania from 1990 to 2007. *Environmental Conservation*: 1-10. DOI: 10.1017/S037689291100035X.

Hall, J., Burgess, N.D., Lovett, J., Mbilinyi, B., Gereau, R.E. 2009. *Conservation implications of deforestation across an elevational gradient in the Eastern Arc Mountains, Tanzania*. *Biological Conservation*, 142(11): 2510-2521.

Hansen, E.H., Gobakken, T., Solberg, S., Kangas, A., Ene, L., Mauya, E., Naesset, E. 2015. Relative efficiency of ALS and InSAR for biomass estimation in a Tanzanian Rainforest. Remote sensing. 2015, 7, 9865-9885. DOI: 10.3390/rs70809865

Huisman, O., de By, R.A (eds). 2009. Principles of Geographic Information Systems. An Introductory textbook. The International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands. 540pp.

Jew, E.K.K., Dougil, A.J., Sallu, S.M., O'cornell, J., Benton, T.G. 2016. Miombo woodland under threat: consequences for tree diversity and carbon storage. *Forest ecology and Management* 361:144-153.

Kashaigili, J.J., Makarius, V.M., Nduganda, A.R., Mbilinyi, B.P. 2013. Integrated Assessment of Forest Cover Change and Above-Ground Carbon Stock in Pugu and Kazimzumbwi Forest Reserves, Tanzania, *Advances in Remote Sensing*, 2:1-9.

Kashindye, A., Mtalo, E., Mpanda, M.M., Liwa, E., Giliba, R. 2013. Multi-temporal assessment of forest cover, stocking parameter and above-ground tree biomass dynamics in Miombo Woodlands of Tanzania. *African Journal of Environmental Science and Technology*, 7(7):611 - 623.

Kimaro, J. and Lulandala, L. 2013. Forest Cover and Land Use Change in Ngumburuni Forest Reserve, Rufiji District, Tanzania. *Journal of Environment and Ecology*, 4(2):113.

Kukkonen, M., Käyhkö, N. 2014. Spatio-temporal analysis of forest changes in contrasting land use regimes of Zanzibar, Tanzania. *Applied Geography*, 5:193 - 202.

Lupala, J.M., Mdemu, M.V., Butungo, S.P. 2014. Effects of Peri-Urban Land Use Changes on Forest Ecosystem Services: The Case of Settlements Surrounding Pugu and Kazimzumbwi Forest Reserves in Tanzania. *Journal of Geography and Geology*, 6(4): 231.

Lupala, Z.J., Lusambo, L.P., Ngaga, Y.M., Makatta, A.A. 2015. The land use and cover change in Miombo woodlands under Community Based Forest Management and its implication to Climate Change mitigation: A case of Southern Highlands of Tanzania. International Journal of Forestry Research, Article ID 459102, 11 pages. http://dx.doi.org/10.1155/2015/459102

Makero, J.S. and Kashaigili, J.J. 2016 Analysis of Land Cover Changes and Anthropogenic Activities in Itigi Thicket, Tanzania. Advances in Remote Sensing, 5, 269-283. http://dx.doi.org/10.4236/ars.2016.54021.

Masanja, G.F. 2013. Population dynamics and the contraction of the Miombo Woodland Ecozone: A case study of Sikonge District, Tabora Region, Tanzania. *Journal of Environmental and Earth Science,* 3(10).

Mayes, M.T., Mustard, J.F. and Malillo, J.M. 2015. Forest cover change in Miombo Woodlands: modelling land cover of African dry tropical forests with linear spectral mixture analysis. *Remote Sensing of Environmental*, 165:203 - 215.

Mbilinyi, B.P., Misana, S., Malimbwi, R.E., Monela, G.C., Jambiya, G. 2007. Land cover dynamics as a result of charcoal production: use of remote sensing and GIS. *Tanzania Journal of Forestry and Nature Conservation*, 76(1), 67 - 79.

Mdemu, M., Kashaigili, J.J., Lupala, J., Levira, P., Liwenga, E., Nduganda, A., Mwakapuja, F. 2012. Dynamics of land use and land cover changes in the Pugu and Kazimzumbwi Forest Reserves. Proceedings of the first Climate Change Impacts, Mitigation and Adaptation Programme Scientific Conference.

Mgaya, N.D., Lyaruu, H.V.M. 2015. Applicability of satellite remote Sensing in accounting above-ground carbon in Miombo Woodlands. *International Journal of Advanced Remote Sensing and GIS,* 4(1):1334-1343.

Millington, A., Townsend, R. 1989. Biomass assessment of SADCC member states. London: Earthscan.

MNRT 1998. National Forest Policy. Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, Dar Es Salaam. 59pp.

Mongo, C., Eid, T., Kashaigili, J.J., Malimbwi, R.E., Kajembe, G.C., Katani, J. 2014. Forest cover changes, stocking and removals under different decentralized forest management regimes in Tanzania. *Journal of Tropical Forest Science* 26(4):484-494

Ndumbaro, F.G.J. 2015. Understanding Spatial Flow of Building Poles' Opportunities and Challenges for Sustainable Livelihoods and Forest Resources: The Case of Zanzibar, Tanzania. *Journal of the Geographical Association of Tanzania,* 36(2): 59 – 72.

Nduwamungu, J., Bloesch, U., Munishi, P., Hagedorn, F., Lulu, K. 2008. Recent land cover and use changes in Miombo woodlands of eastern Tanzania. *Tanzania Journal of Forestry and Nature Conservation,* 78(1).

Nzunda, N., Munishi, P. K., Kashaigili, J., Soka, G., Monjare, J. 2013. Land use and vegetation cover dynamics in and around Kagoma Forest Reserve in Tanzania. *Journal of Ecology and the Natural Environment*, *5*(8).

Ojoyi, M.M., Antwi-Agyei, P., Mutanga, O., Odindi, J., Abdel-Rahman, E.M. 2015. An analysis of ecosystem vulnerability and management interventions in the Morogoro region landscapes, Tanzania. *Tropical Conservation Science,* 8(3).

Pelkey, N.W., Stoner, C.J., Caro, T.M. 2000. Vegetation in Tanzania: assessing long term trends and effects of protection using satellite imagery. *Biological Conservation* 94:297-309.

Pfeifer, M., Platts, P.J., Burgess, N.D., Swetnam, RD., Willcock, S., Lewis, SL., Marchant, R. 2012. Land use change and carbon fluxes in East Africa quantified using earth observation data and field measurements. Environmental Conservation 40 (3): 241–252.

Platts, P.J., Burgess, N.D., Gereau, R.E., Lovett, J.C. , Marshall, A.R. , McClean, C.J., Pellikka, P.K.E., Swetnam, R.D., Marchant, R. 2011. Delimiting tropical mountain ecoregions for conservation. *Environmental Conservation,* 38(3):312–324.

Prins, E., Kikula, I.S. 1996. Deforestation and regrowth phenology in miombo woodland - assessed by Landsat Multispectral Scanner System data. Short Communication. *Forest Ecology and Management* 84:263 - 266.

Soka, G., Nzunda, N. 2014. Application of remote sensing and developed allometric models for estimating word carbon stocks in a North Western Miombo Woodland landscape of Tanzania. *Journal of Ecosystems*, 8pp.

Solberg, S., Gizachew, B., Naesset, E., Gobakken, T., Bollandas, O.M., Mauya, E.W., Olsson, H., Malimbwi, R., Zahabu, E. 2015. Monitoring forest carbon in a Tanzanian woodland using interferometric SAR: a novel methodology for REDD+. *Carbon Balance and Management,* 9(10):14.

Swetnam, R.D., Fisher, B., Mbilinyi, B.P., Munishi, P.K.T., Willcock, S., Ricketts, T., Mwakalila, S., Balmford, A., Burgess, N.D., Marshall, A.R., Lewis, S.L. 2011. Mapping socio-economic scenarios of land cover change: A GIS method to enable ecosystem service modelling. *Journal of Environmental Management* 92:563 – 574.

Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., Steininger, M.K. 2010. Forest and Woodland Cover and Change in Coastal Tanzania and Kenya, 1990 to 2000. *Journal of East African Natural History,* 99(1):19 – 45.

Tabor, K., Kashaigili, J.J., Mbilinyi, B., Wright, T.M. 2016. Forest Cover and Change for the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya circa 2000 to circa 2010. Final report [http://www.birdlife.org/sites/default/files/attachments/cepf_easternarcandcf_forestcover_1.pdf] site visited on 11th October 2016.

Tanzania Forest Service Agency 2015. Main result. National Forest Resources Monitoring and Assessment of Tanzania Mainland. Government printer. 124pp.

Tarimo, B., Dick, O.B., Gobakken, T., Totland, O. 2015. Spatial distribution of temporal dynamics in anthropogenic fires in miombo savanna woodlands of Tanzania. *Carbon Balance Management,* 10:18.

Wang, Y., Bonynge, G., Nugranad, J., Traber, M., Ngusaru, A., Tobey, J., Hale, L., Bowen, R., Makota, V. 2003. Remote Sensing of Mangrove Change along the Tanzania Coast. *Marine Geodesy*, 26:35-48.

Willcock, S., Phillips, O.L. , Platts, P.J. , Balmford, A., Burgess, N.D., Lovett, J.C., Ahrends, A., Bayliss, J. , Doggart, N. , Doody, K. , Fanning, E., Green, J.M.H., Hall, J., Howell, K.L., Marchant, R. , Marshall, A.R., Mbilinyi, B., Munishi, P.K.T., Owen, N., Swetnam, R.D., Topp-Jorgensen, E.J., Lewis, S.L. 2014. Quantifying and understanding carbon storage and sequestration within the Eastern Arc Mountains of Tanzania, a tropical biodiversity hotspot. *Carbon Balance and Management*, 9:2.

IMPACT OF EXISTING AGROFORESTRY PRACTICES ON LOCAL COMMUNITIES' LIVELIHOODS AROUND MAGAMBA NATURE RESERVE IN LUSHOTO DISTRICT, TANZANIA

[1]Kagosi, P.J., [1]Mndolwa, M.A., [1]Japhet, E.M., [2]Sabuni, F. and [2]Kirenga, R.
[1]Tanzania Forestry Research Institute, P.O Box 1854, Morogoro.
[2]Eastern Arc Mountain Endowment Fund, P.O. Box 6053, Morogoro
Corresponding author email: *pjkagosi@yahoo.com*

ABSTRACT

The study was conducted to community adjacent Magamba Nature Reserve (MNR) in Lushoto district, Tanzania to assess: impact of existing Agroforestry (AF) practices on surrounding communities' livelihoods; and challenges for AF practices adoption Four villages namely Mavumo and Kinko (leeward), Migambo and Kwembago (windward) were purposively selected. Data were collected through socio-economic survey using the following methods: Participatory Rural Appraisal, Physical Observation, Structured Questionnaire (SQ) and Key Informants' Interviews. For SQ, sampling intensity of 5% of households in each village was used and questionnaire data were analysed using statistical packages for social science. The qualitative data were subjected to content analysis. Results showed that AF practices in the study area dated way back 1980s. In 1970s free livestock grazing caused considerable surface runoff, soil erosion and reduction of crop production. Since 1980s, the area received various interventions on land conservation and improved livelihood through practising AF. Results showed that 44% and 80% of respondents reported improvement in crop productivity and increased availability of firewood respectively. A total of 80% of respondents reported a decrease in soil erosion. Irrigation farming has improved as a result of year round availability of water flow from MNR. The main challenges reported in adoption of AF are inadequate AF training and poor quality of AF tree species. The study recommends for homegarden in the windward and woodlots in the leeward. The study further recommend on continued training on new AF technology packages including good quality of AF trees species in the study-area.

Key words: Agroforestry, challenges, communities' livelihood, Magamba Nature Reserve, Opportunities.

INTRODUCTION

Agroforestry (AF) is a collective name for land use systems and practices in which woody perennials (trees, shrubs etc) are in crop field (Young 1989, SECAP, 1991). Agroforestry as mixed systems of agriculture in combination with trees and grasslands have formed key elements of some Tanzania landscapes throughout historical times (ICRAF, 2008). Some of these have been documented, like the Chagga home-gardens, the related Mara region home-gardens (*Obohochere)* (Kitalyi *et al*., 2010) the traditional Wasukuma silvopastoral system (*Ngitili*), Kagera homegardens (Rugalema *et al.,* 1994) and the Usambara traditional AF practices (Msuya *et al.*, 2008). AF is a popular practice capable of meeting rural development needs, environmental sustainability and biodiversity conservation due to its capacity to transform lives and landscape (ICRAF, 2008). While AF has potential for reducing land degradation, poverty and enhancing food security and environmental resilience, there are major challenges to wider adoption of AF in Africa (Tanzania inclusive) (Boeckmann and Iolster, 2010).

Magamba Nature Reserve (MNR) is one of the nine nature reserves in the Eastern Arc Mountains (EAMs) with an area of 8,700 ha (EAMCEF, 2013). It is the largest among the 14 forest reserves in the West Usambara Mountains (WUMs) with high biological diversity of both flora and fauna. Notwithstanding this potential, it is heavily depended by surrounding communities for socio-economic development. Study by Namwata *et al.* (2012) in the WUMs revealed that AF has potential in improving livelihoods of rural poor and reduce dependence on natural forests due to their high level of productivity. Increasingly, UNESCO (2010) and Wagner and Lugazo (2011) revealed the problem of heavy dependence on forest products for livelihood by communities surrounding nature and forest reserves. The authors also recommended the need for potential livelihood alternatives to offset forest based livelihood. This paper presents the impact of the existing AF practices on local peoples' livelihood around MNR. Specifically, the paper presents history and current status of AF practices, challenges for adoption of AF practices/technologies and recommend on best AF practices that can be adopted and act as alternative livelihood to offset nature reserve based livelihood.

STUDY AREA AND METHODS

Study area

The study was conducted in four villages Migambo, Kwembago (on the windward), Kinko and Mavumo (on the leeward) within Lushoto district in Tanga region. Topographically the district is mountainous (altitudes 600 - 2300 meters above sea level) (Huwe and Mwihomeke, 1990) with steep slopes (Kihiyo, 1985). The MNR is surrounded by 21 villages. The area has relatively cool and less humid climate with maximum temperatures of 18^{0}C in March and minimum in July (Wiersum *et al*., 1985) with the extreme temperatures of 8^{o}C during cold seasons and 30^{o}C during hot (Nasser *et al*., 1993). It receives an average of 800 - 2000 mm of rainfall with extreme variation within the year which allows for no fixed cropping calendar (Huwe and Mwihomeke, 1990).

Soils are predominantly ancient, more or less leached and very low in phosphorus and potassium, except for some valley alluvium soils (*vitivo*) which were found to be quite fertile (Koert, 1904). Except for the seasonally flooded loamy, blackish – brown alluvium soils of the lower valleys, which are quite deep and fertile, the larger part of the district has deep red earth soil with surface pH of 5.5 (Borota, 1969). The area is covered with parches of montane forest dominated by *Albizia maranguensis, Juniperus procera, Newtonia buchananii, Ocotea usambarensis, Parinari excelsa, Podocarpus usambarensis* and *Syzigium guinense* (Hamisy and Mathias, 2001). Farming is based on the rainfall patterns where sweet potatoes, maize, irish potatoes and vegetables are grown. Perennial crops (coffee, tea, cardamom, banana, spices and fruits) are also planted.

METHODS

Data collection and analysis

The study was conducted in four villages Migambo, Kwembago (on the windward), Kinko and Mavumo (on the leeward) adjacent to MNR. Participatory Rural Appraisal (PRA), Focus Group Discussions (FGDs), Physical Observation (PO), Structured Questionnaire (SQ) and Key Informants' Interviews (KII) were used in data collection. For structured questionnaire, household was used as sampling unit and sampling intensity of 5% of village households was used. A random sample of at least 5% taken from the total household population to represent significant population is recommended (Boyd and Stach, 1988). Both qualitative and quantitative data were collected. Information collected through socio-economic survey included; history of AF practices, current status of AF practices, challenges facing adoption of AF practices and available opportunities that can improve adoption of AF practices.

Data analysis

Data collected through FGDs, PRA, PO, and KII were subjected to content analysis. The content analysis is a technique for compressing many words of text into fewer content categories based on explicit rules of coding (Stemler, 2001). In this case, the recorded dialogues were broken down into smallest meaningful units of information or themes. This helped researchers in ascertaining the types, patterns, sequences and process of issues related to impact of AF on community livelihoods around MNR. Data collected through PRA tools (pair-wise ranking and time line history) was analyzed with the help of local people. Matrix/pair-wise ranking was used to identify the most popular AF practices and challenges faced by communities in managing AF. It was also used in ranking the best AF system based on the choice of the communities. The quantitative data collected through household structured questionnaire was analyzed statistically using Statistical Package for Social Science (SPSS).

RESULTS AND DISCUSSION

Characteristics of respondents

It was found that the sampled household had 58% male and 42% female headed households. Eighty eight percent (88%) of respondents were married (Table 1). The married families indicated a stable labour for the AF activities. It was reported that men were more involved in AF activities especially those done away from homesteads. According to Hunt (2004) male and female have different needs, roles and responsibilities. For example men and women value tree species best for AF and their uses differently. Many women concentrated in planting trees in home gardens for fruits, medicine and other products for households use or sale in local markets.

Table 1: Characteristics of the respondents

Variable	Characteristics	Frequency (N)	Percentage (%)
Gender	Male	67	58
	Female	49	42
	Total	116	100.0
Education level	No formal education	8	6
	Primary education	97	84
	Secondary education and above	11	10
	Total	116	100.0
Marital status	Single	8	7
	Married	10.2	88
	Widowed/widower	6	5
	Total	116	100

Majority (84%) of respondents had primary education, followed by 10% with secondary education or above and 6% with no formal education. Education is necessary to enable someone to easily adopt and transform new technologies in economic activities. Mhinte (2001), pointed out that education increases working efficiency, productivity, high income and food security at household level.

It was also found that mean age of household heads of the population in the study area was 45 years indicating that most of the respondents were in the economically productive age which has an impact in undertaking AF activities. According to Mandara (1998) and Mtenga (1999), household members were considered economically productive between 16 to 64 years. Presence of this group indicated a sufficiency in supply of workforce needed in AF activities.

The average family size in the study area was 5 household members. The figures showed conformity with average district figures of 5 persons per household (URT, 2012) but lower than average of 9 persons reported by Moshi (1997) in the west Usambara. This could be due to the youth emigration from the study area to the towns searching for better life outside the district as a result of limited resources such as land. The emigration of youth to town has negative impact in the reducing workforce needed for AF activities in the area.

History and current status of AF practices around MNR

History of AF in the study area

According to Johansson (2001), land degradation in WUM started to receive attention during German era between 1930 and 1945. Johansson (2001) further reported that during that time solution to land degradation concentrated on construction of bench terraces, tied ridges, enforced de-stocking, afforestation, prohibited cultivation on steep slopes and resettlement of local people to lowland areas. These measures were implemented by force and made local farmers to hate the whole idea of soil conservation (Conte, 1999). Land degradation continued to post colonial era (after independence of Tanzania - then Tanganyika) in 1961.

Increasing population in the district caused increased pressure for land resource. It was reported that during this period the area faced serious soil erosion which resulted from poor soil conservation measures plus free livestock grazing which caused considerable surface runoff, soil erosion and reduction of crop production. In 1980s several Governmental, Non-Governmental Organizations (NGO) and international donor programs provided considerable solution to the soil erosion problems. Among them were; Lushoto Integrated Development Project (LIDEP), Participatory Agriculture Development Empowerment Project (PADEP), Soil Erosion Control and Agroforestry Project (SECAP) and Tanzania Social Action Fund (TASAF), Tanzania Forest Conservation Group (TFCG) as well as local government. Each intervention had its impact based on the planned activities. SECAP dealt with introduction of tree seedlings and cattle keeping in the villages through calves pass over from one farmer to another. PADEP promoted establishment of trees nurseries to the villages. Similar support was obtained from Shume Forest project in different stages. Awareness creation was done to Village Government Leaders (VGL) and councils and public through village meetings.

In year 2011, TASAF came in and introduced support to poor families through dairy cattle keeping. The later was for improvement of the household economies but at the same time to support supply of manure in the field. LIDEP provided support in tree nursery establishment through provision of tree seed and nursery inputs just like TFCG. The commonly preferred trees were *Grevillea robusta, Cupressus lusitanica* and coffee. The practice also involved planting of guatemala (*Tripsacum laxum*) grass for pasture (feeding animals). This was the time when zero grazing was emphasized. On the other hand, Ministry of Natural Resources and Tourism (MNRT) in 1990s supported the village through MNR in establishment of tree nurseries. Later the District Development Director (DED) added some effort and provided support of seedlings to the village.

Beside general acceptance that genesis of AF within WUM can be traced way back 1900s (Scherr, 1990) the scenario thereafter did not take the same trend in all areas. Scherr (1990) further indicated that originally AF involved the use and protection of trees mostly through natural regeneration of valuable tree species and shrubs for fodder, fuel wood, medicines and building materials. The practice was reported to be done by the local people although not in a pronounced level as it is to-date. Available records showed that the habit of retaining trees formed the basis for present AF (Munishi *et al.*, 2006) and that local people grew with it building up love with the practice.

Current status of AF practices around MNR

AF technologies

The commonly practiced AF technologies in the study area were agri-silviculture, epi-silviclture, woodlots, boundary planting, agri-silvi-pastoral, home-gardens and alley cropping/hedgerow intercropping. According to (Rugalema *et al.*, 1994) alley cropping is peculiar as it retains the basic restorative attributes of the bush fallow through nutrient recycling, fertility regeneration and weed suppression and combines these with arable cropping so that all processes occur simultaneously on the same land, allowing the farmer to grow crops in the land for an extended period. Alley cropping/hedgerow planting and home-garden were practiced by 28% and 20% respectively. Other practices were done by over 30% participants.

Common to both areas (windward and leeward) were the woodlots, boundary planting and epi-silviculture. Agri-silviculture ranked high as it was practiced by 61% of population in both areas. The practice is more pronounced in both areas but was observed to be more prominent in Kinko and Mavumo villages (leeward) where it was practiced by 52% and 83% of households respectively. It was established that these communities in average had relatively larger pieces of land compared with Migambo and Kwembago (windward) (Table 3). In common woodlots received the lowest attention in all villages. This might be because in woodlots land is held for much longer time without producing alternative crops. Because of this; areas with land shortage have little chance of practicing it. On the other hand the differences are contributed by the fact that the two areas were reported to differ climatically with the former receiving relatively less precipitations than the later. It is interesting to note that home gardening is more practiced in Mavumo village (40%) than the rest. Kinko was the least in practicing home gardens despite the fact that TASAF came in and introduced support to poor families through dairy cattle keeping in 2011. The fact is, people had no much interest in home-gardening in Kinko just because they have relatively larger piece of land than other studied villages

Reasons for adopting AF

There had been a number of reasons as to why households glued to AF. Majority (80%) of respondents mentioned production of firewood and 65% soil conservation as the major reasons for practicing AF (Table 2). This was contrary to observations reported by Munishi *et al*., (2006) where wood/timber production ranked high in trees retained on farms. Reasons for practicing AF in the study area varied from one village to another (Table 2).

Table 2: Reasons for adopting AF in the study area as reflected by proportions of respondents'

Village	Soil Conservation	Provision of Firewood	Maximize production	Fodder for livestock	Shade	Wood	Boundary demarcation
Mavumo	57	63	70	20	0	30	0
Kinko	76	84	40	4	4	36	4
Migambo	58	81	52	10	0	39	0
Kwembago	70	93	43	0	0	23	3
Average	65	80	52	9	1	32	2

The results further showed that 44% and 80% of respondents reported improvement in crop productivity and increased availability of firewood respectively. A total of 80% of respondents reported a decrease in soil erosion (Table 3). Irrigation farming has improved as a result of year round availability.

Table 3: Respondents' opinions (percentage) on crop productivity and soil erosion

Item	Mavumo	Migambo	Kinko	Kwembago	Average
Increase crop productivity in 10 years (%)	30	49	44	53	44
Reduced soil erosion	60	87	84	90	80

Impact of AF on households' livelihood

AF is a promising alternative, which is considered as one of the options to lift local communities out of the poverty trap (ICRAF 2008). It was found that dependency on the forest products from MNR has tremendously been reduced. The following reasons were reported; (*i*) Improved law enforcement by the MNR management, and (*ii*) Increased realised returns from other sources including AF plots. It was found that in average households realized 67% of their income from AF related activities (54%) forest products and 13% agriculture crops) (Figure 1). The main sources of income reported in the study area were those from within and outside AF activities (Figure 1). In general, the household gets total of Tshs 1,443,117 per year from sale of both forest products and agricultural crops from AF plots. The major AF forest crops sold from AF plots were firewood followed by timber. The values for timber included also values of that wood used by 32% of respondents for households' construction. Charcoal making from AF plots was uncommon in the studied villages.

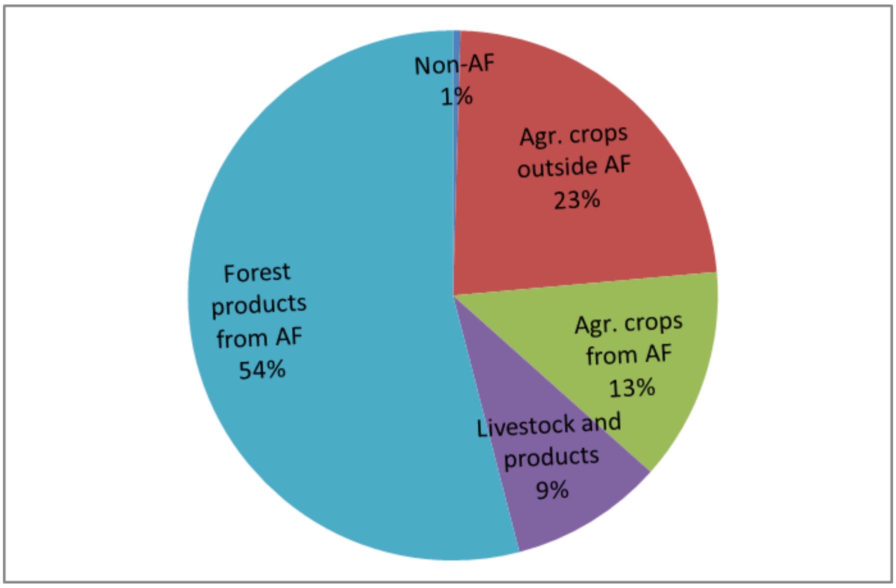

Figure 1: Average percentage contribution of various household economic sources

Furthermore, it was reported that income from sale of AF products was mainly used for buying food (during shortage) and other household needs. However, it was found that majority (80%) of respondents in the study villages get enough food all year round due to increased crop production. The few respondents (20%) who experience food shortage subsidize it by using money obtained from sale of AF products. At the same time extra income was used on other expenditures such as school fees, purchase of land, business expansion, settling of hospital bills and purchase household assets like bicycle, motorcycle and mobile phones.

Firewood was the main source of energy in the study area. The material is collected from either felled or pruned branches from on farm trees. It was further found that 80% of respondents reported an increase in fuelwood supply from AF plots. Some (72%) respondents agreed that crop production has increased and had even a chance of diversifying agricultural crops. Income realised from sale of products harvested from AF plots contributed so much in raising households' economy.

Increased water flow and improved agriculture

Water for irrigation was a big problem in the past. It was realized that, the presence of forest products harvested from AF plots paved way for improvement of the MNR vegetation hence stabilized water flow. Previously water used to flow for only six months. However, currently water is available throughout the year and that farmers can presently (especially at Kinko village) increase crop production through irrigation. It was accepted that the money realised from production of agricultural crops and sale of AF products has raised standard of living of the respective households by being able to send their children to school, buying food (for supplement) as well as building good settlements.

Improved livestock keeping

AF practices have improved livestock keeping from free range to zero grazing. It was learnt that as a result of increased participation in AF, number of livestock has been reduced tremendously. In average households had about 2-3 cows and 4-5 goats in Mavumo village, 2-3 cows and 1-2 goats in Migambo village. The number of cows in Kwembago village is quite low to one per household. Kinko had relatively many cows (3-5 in average) per household and 4-5 goats. The decreased number of animals was a result of strict by-law which does not allow for free grazing. Goats, cattle and sheep were kept in zero grazing where fodder was brought from AF plots far from home (**Plate 2**). It was also learnt that with increasing population, the study area sometimes fell short of fodder and pasture land. Beside reducing erosion, contour line fodder production in the villages provided considerable amount of forage for zero-grazing hence increased milk production for the small-scale dairy farmers.

Plate 2: Women carrying fodder from AF plots far from home

Unfortunately, it was observed that environmental benefits realized from AF plots were given little value than direct cash and in-kind benefits. Consideration on contribution of the AF plots in global environmental benefit like carbon sequestration and biodiversity conservations was not of priority to farmers.

CHALLENGES AND OPPORTUNITIES OF AF PRACTICES

Challenges

It was observed that challenges faced by farmers differed with location. Below are some of the reported challenges;

(i) Diminishing farm land sizes

It was found that 41% of the households in the leeward had more than 2 acres of farms compared to 30% from the windward (Table 3). This situation has great impact in adoption of AF. Those households with small land pieces avoided engaging themselves in some AF practices like woodlots. In general 75% of the households reported to own less land than what they needed.

Table 3: Farm sizes between two areas (leeward and windward)

Location	Village	Farm sizes (acres)				
		≤ 1	1.1-2.0	2.1-3.0	3.1-4.0	>4
Leeward	Mavumo	48	22	18	11	0
	Kinko	9	36	22	13	18
	Average	29	29	20	12	9
Windward	Migambo	28	38	21	7	7
	Kwembago	33	33	17	1	7
	Average	31	36	19	4	7

NB: Numbers inside the table represent proportion of respondents

The need for other pieces of farming land was a crosscutting challenge among villages in the study area. While some (38%) respondents were ready to purchase any available piece of land within their village, others (16%) were ready even to go outside their village as far as Handeni/Kilindi. Migambo village had more (23%) respondents ready to go outside the village to purchase land while Mavumo had the least (10%). On average 48% of households were ready to purchase farm lands elsewhere. With increasing population, larger areas are now being converted into residential areas and for construction of other social services like schools and dispensaries. This stressed land for AF the more and increased more demand of wood from AF plots in the expense of areas for establishing AF plots.

(ii) Restrictions in harvesting of forest products from AF plots

Tree harvesting ban has stopped or made it difficult for farmers to harvest planted AF trees freely. It was learnt that if one wants to harvest a tree, he/she has to follow a series of permit search processes from village level up to the district commissioner, which is very stressful. It was argued, that before the ban, the cost for house construction, payment of school fees and hospital bills were mainly paid through sell of AF trees. Since AF is one of the main employer of large number of people in the study area, restrictions on AF tree harvesting has consequently increased poverty at household level. It was reported that a proper arrangement is needed so as to allow harvesting at a certain maturity age and encourage replacement of cut trees. It was further revealed that, AF harvest ban discourages farmers from engaging in planting more trees in the study villages. This arrangement needs a review.

(iii) Improper functioning of village governments

The other challenge observed was improper functioning of government machineries at village level. Instead of emphasizing on tree planting; much concentration was in issuing of harvest permits and administering penalties to offenders. This attracted for a quick implementation of tree harvest ban which resulted to economic crisis and which opened chances for corruptions and illegal harvesting and sometimes encroachment to MNR. The Village Environmental Committees need to be more educated.

(iv) Poor knowledge on trees crops site matching

Tree planting and environmental conservation training has been provided by various government organizations and non-governmental organizations in the district. However, training was in many cases done infrequently or even provided once. It was reported that training left behind new comers and young farmers every year. In general training lacked continuity. This had a very serious effect in that those who received the training were supposed to impart the required knowledge to others which was not always the case. In some occasions those people were noted to move/shift to other areas. Knowledge on matching tree species to site was in this case missing. As a result farmers kept on growing pines and sometime eucalyptus mixed with other agricultural crops which reduced production of the later. Pine and eucalyptus were supposed to be planted in the woodlots or as boundary trees. Sometimes trees like teak (*Tectona grandis*) were found incorrectly planted in the study area. It was learnt that during SECAP, the approach was to villages and not individual farmers, and the main extension instrument was group meetings. Unfortunately, it was noted that men were main decision makers while women were implementers. Competence of planning and implementation was partly delegated to zones and village levels rather than key or pilot farmers. This approach missed the succession scenario.

(v) Damage from wild animals

Villagers especially those with plots adjacent to MNR complained of wild animals destroying their crops. This tempted the farmers not to include trees in their farms as the animals would use them for hiding and eat agricultural crops.

(vi) Influence of climate change

There have been negative changes especially on rising temperatures and irregular rainfall which consequently affected planting patens and production of almost all crops. This was reported by many (85%) respondents. The drier areas had become much drier with an unusual prolonged dry spells (sometimes up to six months). This in a way caused a big change in the formation of the AF systems, as weather plays a very big role in trees/vegetation establishment, growth and development which sometimes commands for change in alternative AF tree species.

(vii) Poor quality of tree planting materials

Lack of improved planting materials (seeds, seedlings, cuttings/clones) was identified as one of the biggest challenges constraining AF farming system in Lushoto District. Poor quality of seed is probably due to that, farmers cut the best trees in their plots without leaving behind high quality trees to produce tree seeds for future generation and access to Tanzania Tree Seed Agency (TTSA) for genuine tree seed was limited. The deficit might also be a result of incompetence of farmers in handling the seeds.

(viii) Improper harvesting

Improper harvesting appeared to be a setback in management of AF plots. Generally, to make the process sustainable, harvesting and planting should move concurrently. However, there were many cases where some plots were left bare with all trees harvested without any replacement plan (Plate 3), and the decrease is alarming (Munishi *et al.*, 2006).

Plate 3: Excessive removal of trees (*G. robusta*) leaving an AF plot without trees

CONCLUSION AND RECOMMENDATIONS

Agroforestry has a long history in the study area and passed through various interventions. The interventions had positive impact in the households' livelihood as the practice provided employment to most farmers in Lushoto District. Farmers were motivated by AF impacts, encouraging each household to practice it. It has contributed into improvement of households livelihoods with direct income benefit as well as indirect through improved areas such as water flow from MNR. However, various challenges such as limited training, poor AF tree seedlings, restrictions in harvesting AF trees, fluctuations in climatic conditions, and land shortage limit practicing of AF. It is recommended that, proper AF practices training need to provide to stakeholders and all AF practices need to continue to be practiced in the study area depending on the physical and climatic conditions of the respective area. However, homegarden need to be emphasised in the windward area because of land shortage and woodlots in the leeward area as there are relatively larger pieces of land per household.

ACKNOWLEDGEMENTS

We wish to acknowledge the EAMCEF for financial support. Many thanks should go to TAFORI officials for transport/office facilities. Lastly but not least, special appreciation goes to village leaders and all farmers who shared their experiences with project team. Many thanks to all people who provided help and information during the research and writing of this paper.

REFERENCES

Boeckmann, S. and Iolster, P. 2010. Agroforestry in Africa: Exploring the Lack of Widespread Implementation and the Potential for Expansion. http://www.rmportal.net/library.

Borota, J. 1969. The growth of tree species in Lushoto arboretum. Tanzania Silviculture Research Note. 23. Lushoto, Tanzania.

Boyd, H.K. and Stach, S. F. 1988. Marketing Research. Texts and Cases. Illinois Richards D. Inc., London. 813pp.

Conte, C.A. 1999. The forest becomes desert: Forest use and environmental change in Tanzania's West Usambara Mountain. *Land Degradation and Development*, 10:291-309.

EAMCEF 2013. Baseline Survey Report for 8 Nature Reserves and 1 National Park in the Eastern Arc Mountains of Tanzania. Morogoro, Tanzania 220pp.

Hamisy, W.C. and Mathias, S. 2001. Survival and growth of three *Liquidamber styraciflua* provenances at Lushoto, Tanzania. *TAFORI Newsletter*, 2(1): 7 – 13.

Huwe, C. and Mwihomeke, S. 1990. Development and Research Activities within the Soil Erosion Control and Agroforestry Project in the West Usambara mountains – Tanzania. Paper presented in the Workshop on "participatory methods for on-farm, Agroforestry Research" ICRAF Nairobi, February 1190. 19pp.

Hunt, J. 2004. Introduction to gender analysis concepts and steps. *Development Bulletin*, 64:100-106.

ICRAF (World Agroforestry Centre). 2008. Integrating livelihoods and multiple biodiversity values in Landscape Mosaics: field methods. 48pp.

Kihiyo, V.B.M.S. 1985. An economic evaluation of some aspects of the wattle industry in Tanzania. MSc thesis, Sokoine University of Agriculture, Morogoro, Tanzania

Koert, W. 1904. Geologische – agronomische der Umgegend von Amani in Ostusambara. Miteinergeologisch – agronomischen Übersichts-kerte-Ber. Land. Forstw. D.O.A 2: 143-164.

Kitalyi, A., Nyadzi, G., Lutkamu, M., Swai, R. and Gama, B. 2010. New Climate, New Agriculture: How Agroforestry Contributes to Meeting the Challenges of Agricultural Development in Tanzania, *Tanzania Journal of Agricultural Sciences*, 10(1):1 - 7.

Mandara, E.G.1998. Assessment of factors influencing women's participation in off-farm income generating activities. Dissertation for Award of MSc Degree at Sokoine University, Morogoro, Tanzania, 101pp.

Mhinte, A.R. 2001. Analysis of Food Insecurity and Household coping strategies: The case study of Kilosa District. Dissertation for award of MSc. degree at Sokoine University of Agriculture, Morogoro, Tanzania. 122pp

Msuya, T.S., Mndolwa, M. and Kapinga, C. 2008. Domestication: An Indigenous Method in Conserving Plant Diversity on Farmlands in West Usambara Mountains. *Journal of Tropical Forest Science* 46 (Suppl.1): 74 – 78.

Moshi, E.R.F. 1997. Inventory of indigenous agroforestry systems in the West Usambaras, dissertation for award of Msc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 172pp.

Mtenga, K.J. 1999. Smallholder seed production in Tanzania: Potential and Limitations. Dissermination for award of Msc degree at Sokoine University of Agriculture, Morogoro, 96pp

Munishi, P.K.T., Philipina, F. and Temu, R.P.C. 2006. On-farm Tree Resources and Farmer Motives for on farm Tree Retention and Management in Bumbuli Ward, Lushoto District North Western Tanzania. In: In: S.A.O Chamshama, L. Nshubemuki, S. Iddi, R.E Swai, M.L. Mhando, E.sabas, C. Balama, L. Mbwambo and M. Mndolwa (Eds). *Proceedings of the Second National Agroforestry and Environment Workshop (Partnerships and Linkages for a Greater Impact in Agroforestry and Environmental Awareness),* Mkapa Hall, Mbeya Tanzania 14th – 17th March 2006. pp 188 - 198.

Namwata, B.M.L.; Masanyiwa, Z.S. and Mzirai, O.B. 2012. Productivity of the agroforestry systems and its contribution to household income among farmers in Lushoto District, Tanzania. *International Journal of Physics and Social Sciences*, 2(7): 369-292.

Rugalema, G.H., Johnsen, F.H., Okting'ati, A. and Minjas, A. 1994. The homegarden agroforestry system of Bukoba district, North-Western Tanzania. 3. An economic appraisal of possible solutions to falling productivity. *Agroforestry Systems*, 28(3):227–236.

Scherr, J.S. 1990. Evaluating Farmers' Agroforestry Systems. Paper presented to the DSO Training Course on Agroforestry Research and Development. (Unpublished). ICRAF House, Nairobi. Pp 15.

SECAP 1991. Project review. Soil Erosion Control and Agroforestry Project, Lushoto.

Stemler, S. 2001. An overview of content analysis. Practical Assessment, Research and Evaluation. [http://PAREonline.net/getvn.asp?v=7&n=17] site visited on 2/10/2014.

UNESCO 2010. Nomination of properties for inclusion on the world heritage list serial nomination: Eastern Arc Mountains forests of Tanzania. Online document available at: http://whs.tfcg.org/docs/E_Arc_Mountains_World_Heritage Nomination _100127_FINAL.pdf] Site visited on 21/10/2012

URT 2012. Population and housing census, National Bureau of Statistics and Office of Chief Government Statistician, President's Office, Finance, Economy and Development Planning Zanzibar. 244pp.

Wiersum, K.F., Anspach, C.L., Boerboom, J.H.A., Rouw, A. and Veer, C.P. 1995. Development of ecological methods of upland farming in West Usambara Mountains, Tanzania. *FAO Forestry Paper* 5: 55 – 82.UNESCO/FAO. 1977. Soil of the World. 1:5 000 000.00 Vol. VI Africa. FAO Rome.

Young, A. 1989. *Agroforestry for Soil Conservation*. CAB International. ICRAF.

ANNOUNCEMENTS

In the Period of 2009-2017, TAFORI has witnessed retirement of her 49 employees. These served in various capacities. We witnessed our Director General Dr. Ladislaus Nshubemuki who retired from service in 12.01.2010.

The other TAFORI members served in the capacity of Researchers, Laboratory Technicians, Forest Assistants, Librarian, Typist, Drivers and Security Guards. To all of you we say "Thank you" for the foundation laid and we wish you well in your endeavours. The list of retired TAFORI employee is as indicated below:

S/N	NAME	DATE OF BIRTH	DESGNATION	QUALIFICATIONS	DATE OF RETEREMENT	CENTRE
1	Dr. Ladislaus Nshubemuki	13/01/1950	CRO, DG	Ph.D,1990	12/1/2010	HQ
2	Mr. Theonas Msangi	4/3/1951	SRO I	M.Sc(For), 1991	3/3/2011	Lushoto
3	Mr Alex Chihongo	28/12/1952	SRO I	M.Sc(Wd Sc.),1979	27/12/2012	HQ
4	Mr. Evarist Sabas	1,Oct,1951	SRO I, DFPR	M.Sc(For), 1980	2,Oct,2011	HQ
5	Mr. Leonard Mhando	12/9/1950	SRO I	M.Sc(For),1991	11/9/2011	HQ
6	Mr. Stephen Mwihomeke	1/12/1952	SRO I	M.Sc(For),1987	30/11/2012	Lushoto
7	Mr. Jocania Isango	1/7/1952	SRO I	M.Sc, 1994	30/6//2012	HQ
8	Mr. Nassoro Magogo	24/1/1951	SLT I	Dip (For),1986	23/11/2011	Lushoto
9	Mr. Samwel Lekamoi	1/4/1952	LT II	Cert (For),1974	30/3/2012	Lushoto
10	Mr. Peter Nduka	23/1/1953	PLT II	Dip (For)1981	22/1/2013	Dodoma
11	Mr. Sawema Msangi	12/4/1951	SLT I	Dip (For),1984	11/4/2011	Moshi
12	Mr. Chrispine Shangali	23/12/1954	PLT II	Dip (For)1979	22/12/2014	Lushoto
13	Mr. Ayubu Shemkongwa	30/12/1948	LT I	Cert (For),1980	29/12/2008	Lushoto
14	Mr. Athumani Kambi	14/3/1955	SLT I	Dip (For),1991	13/3/2015	Kibaha
15	Mr. Ahmed Mndolwa	1/11/1957	SLT I	Dip (For),1990	30/10//2017	Lushoto
16	Mr. Leonce Leringo	1/7/1957	SLT II	Cert (For)	30/6/2017	Malya
17	Mr. Gideon Mushi	22/6/1954	LT I	Dip(For)2006	21/6/2014	Lushoto
18	Ms. Veronika Kweka	23/6/1950	SFA II	Cert, 1973	22/6/2010	Lushoto
19	Ms. Hamida Ngoda	30/9/1952	SFA II	STD VII	29/9/2012	Lushoto
20	Ms. Pilly Kapilya	10/10/1955	SFA II	STD VII,1970	9/10/2015	Kibaha
21	Mrs. Damaris Sabali	26/6/1956	FA III	STD VII,1970	25/6/016	Lushoto
22	Mr. Colman Sabas	1/7/1951	SFA II	STD VII,1966	30/6/2011	Moshi
23	Mr. Protas William M	1/7/1956	SFA II	STD VII,1973	30/6/2016	Moshi
24	Mr. Yahya Said	7/7/1957	SFA II	STD VII,1973	6/7/2017	Lushoto
25	Mr. Hamis	20/3/1952	SFA I	STD VIII,1966	19/3/2012	Sao Hill

	Mng'omba					
26	Mr. Alen Mokiwa	1/1/1952	SFA II	STD VII,1967	31/12/2011	Kibaha
27	Mr. Golitha Malindima	1/7/1956	SFA III	STD VII	30/6/2016	Malya
28	Ms. Anna Issack	20/12/1956	SFA I	STD VII,1976	19/12/2016	Moshi
29	Mr. Joseph Moses	25/5/1954	SFA II	STD VII,1968	24/5/2014	Lushoto
30	Ms. Amina Hemed	13/9/1952	SFA II	STD VII,1964	12/9/2012	Lushoto
31	Mr. Keneth Ndelimo	12/12/1959	FA III	STD VII,1966	11/12/2016	Tabora
32	Mr. Mtoi Juma	1/12/1953	SLA II	Cert, 1981	30/11//2013	Lushoto
33	Mr. Hemed Abdallah	15/6/1957	SLA II	STD VII	14/6/2017	Lushoto
34	Mr. Michael Kicholo	28/12/1952	SLA II	STD VII	27/12/2012	Lushoto
35	Mr. Daniel Jona	14/1/1956	SLA II	STD VII	13/1/2016	Lushoto
36	Mr. Zoel Kiwale	5/7/1955	SLA II	STD VII,1976	4/7/2015	Moshi
37	Mr. Adam Shekiomboo	13/7/1953	SLA III	Cer(For), 1993	12/7/2013	Kibaha
38	Mr. Mwinyijuma Ibrahimu	1/7/1952	SA II	STD VII,1966	30/6/2012	Moshi
39	Mr. Francis Juma	11/6/1951	SA II	STD VII	10/6/2011	Lushoto
40	Mr. Jackson Zakaria M	1/7/1952	SA II	STD VII,1967	30/6/2012	Moshi
41	Mr. Richard Mwaringo	11/1/1957	SA I	Cer (Sawmilling),1982	10/1/2017	HQ
42	Ms. Halima Mshana	8/9/1951	Libr Ass I	Cert(Libr),1997	7/9/2011	Lushoto
43	Ms. Stella Muyanza	8/7/1951	TYPIST I	Cert, 1997	7/7/2011	Lushoto
44	Ms. Eliasenta Lemma	3/12/1949	TYPIST II	Cert, 1998	2/12/2009	Lushoto
45	Ms. Efransia Rwenyagira	1/11/1952	PS II	Cer, 1972	30/10/2012	Moshi
46	Ms. Binti Msangi	1/7/1954	TYPIST II	Cert, 2000	31/6/2014	Kibaha
47	Mr. Mwinyihamisi Mfaume	1/7/1956	Driver Mechc	Adv Cert,II,2002	1/7/2016	Kibaha
48	Mr. Samweli Malogo	1/7/1953	SG III	STD VII	30/6/2015	Malya
49	Mr. Martine. Morgan	1/7/1957	SG III	STD VII	30/6/2017	Malya