Agroforestry as Adaptation Strategy under Climate Change in Mwanga District, Kilimanjaro, Tanzania

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Abstract- **Agroforestry is a climate-smart production system that sustainably diversifies environmental and socio-economic benefits of subsistence farmers, and is therefore considered more resilient than monocropping to increased intensity of extreme weather events. This study was conducted to assess the potential of agroforestry in buffering smallholder`s farmers against climate variability in Mwanga District, Kilimanjaro, Tanzania. Research methodologies used included literature review, questionnaire, and ecological survey. A sample of 103 households engaged in agro forestry (AF) and non-AF were selected randomly from three villages for ecological study which involved an inventory of on farm trees and questionnaire survey for collecting socio-economic data. SPSS computer program was used to analyse socio-economic data. The diversity of benefits in AF practices such as food (59.2%), fodder (58.2%), selling livestock (71%), fruits (54.4%), timber (27.2%) and fuelwood (45.7%) revealed to increase farmer`s resilience during environmental extremes and climate variability. AF practitioners were richer than non practitioners with an extra income of TAS 988 042 (USD 618) annually. In conclusion, crops integration and diversity in AFS were among the resilient features which reduced farmer's risk from total crops failure, since the risk of losses from environmental hazards was spread among different crop species. Further increased income as a result of the diversity of products from the agro forestry system(AFS) enhanced the resilience of AF practitioners. But, vigorous efforts are needed to provide knowledge on the AF products value-addition innovation, promoting rich carbon land use, understanding and addressing competing claims on natural resources access and uses.**

Keywords- Agroforestry Products; Multipurpose Trees; Products Diversification; Resilience; Sustainability

I. INTRODUCTION

Africa is a continent of contrasts wich is gifted with an incredible diversity of ecosystems, natural resources and various economic activities. It is also characterized by conditions of widespread poverty and human insecurity [10]. Climate change represents a threat and challenge to Africa because many households, social groups and regions have a limited capacity to adapt to climate variability and change. References [9] and [10] argued that, eastern and sourthern Africa's vulnerability to climate change is shaped by the complex interaction of social, political, economic, cultural and environmental factors, all of which are likely to be affected by the projected impacts of climate change. Since not everyone and every place in eastern and southern Africa is equally vulnerable to climate change [9], vulnerability to climate change varies greatly among regions, countries, villages, sectors and social groups in eastern and southern Africa. Reference [27] argues the impact of climate change will have a direct effect not only on rain-fed crops, but also on water storage, putting increased stress on water availability for irrigation. These will have direct or indirect impact on the increasing population, socio-economic activity across the continent and therefore decrease availability of land and non-renewable resources. Vulnerability of poor group will also increase, and so reduces adaptive capacity of subsistence farmers' [9]. Since availability of water will be limited, agriculture will compete for other uses of water, further stressing farming systems. Land-use options that increase adaptive capacity of subsistence farmers' and hence less vulnerability to climate change impacts are necessary [4]. Traditional resource management adaptations, such as agroforestry systems, may potentially provide options for improving farmer adapting to climate change through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change [1, 23]. Thus efforts are needed for intensifying management and governance efforts to generate products and services in agroforestry systems [5], through integrating trees in agriculture landscape, cultural landscape, watersheds and adjacent natural forest in order to restore ecosystems [30]. However, these adaptations are possible when combined with traditional resource management systems, agroforestry as a local adaptation, therefore, is a promising area of interest for scientists, policy-makers and practitioners. Tree-based systems are more profitable and less risky than other agricultural options because of the variety of products [18]. First, their deep root systems are able to explore a larger soil volume for water and nutrients, which will help during droughts. Second, increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years [27].

Although adapting to changes in long-term averages may be feasible through technology and germplasm transfer, yet increased climate variability with concomitant increased frequencies of extreme events poses a greater challenge, particularly in the semi-arid tropics (SAT) [1, 27, 32]. The existing of complex land tenure, land use conflict, environmental factors, management and type of AFS which are shaped by the configuration of the Eastern Arc Mountains (North Pare Mountains), river valleys, plateaux and the plains dipping into the Pangani Valley in Mwanga District, is adding another challenge that could have different socio-economic influence on AF practitioners in adapting climate change and variability [7, 29]. This was reflected in both the natural vegetation, the manner in which land was used, types of crops cultivated and agroforestry practiced [10, 25]. Furthermore, there are positive links between agroforestry and adaptation to climate variability, which means agroforestry option may provide a means for diversifying production, increasing resilience of subsistence farmers and buffering against production risk associated with climate [2, 37]. However, there are also examples of constraints on the productivity and benefits of agroforestry system, since some practices reduces adaptive capacity like shifting cultivation and overgrazing. Other includes deforestation, unstainable farming, overstocking and poor land management [8, 10]. In order to understand the role of agroforestry as adaptation to increased climate variability, it is fruitful to look at how populations are coping with current climate variability and extreme events in Mwanga District. In this context, this study aimed at assessing the potential of agroforestry systems in buffering small holders farmer's against climate change and variability in Mwanga District. The objectives are therefore: (1) To determine tree species preferences and uses in agroforestry that reduce vulnerability to climate change; (2) To analyse and compare the various AF and non-AF products and practices that enhance farmer`s resilience against changing climate, and (3) To determine the extent contribution of AF products to total annual households cash income.

II. METHODOLOGY

A. Study Area Descreption

The study was conducted in Mwanga District (37°25′-37°58′ E; 3°25′-3°55′ S) in Kilimanjaro region Tanzania (see Figure 1). It is one of six districts in the region. The district covers an area of 2641 km2. Land area is 2,558.6 km2 and water covers an area of 82.4 km2 of Nyumba ya Mungu Dam and Lake Jipe. The district is characterized by lowlands in the east and west that lie between 550-700 meters above sea level. The highlands have an altitude that ranges from 700-2500 meters above sea level; this is formed by the highlands that form the Eastern Arc Mountains. It is particularly known for coffee production and complex agroforestry systems. It experiences 400-600 mm of rainfall per annum in the lowland and between 800-1250 mm in the highlands. There are two distinctive rain seasons, short rainfall from October-December and Long rainfall from March-June. The highlands enjoy both the short and long rain seasons. The district experiences some strong and dry winds blowing normally form the East to the West. Temperatures range between an average of 14 ℃ during June-July and 32 ℃ usually in January. Land is covered by shrubs of *acacia species* in both eastern and western lowland and forest around the mountain in the highlands.

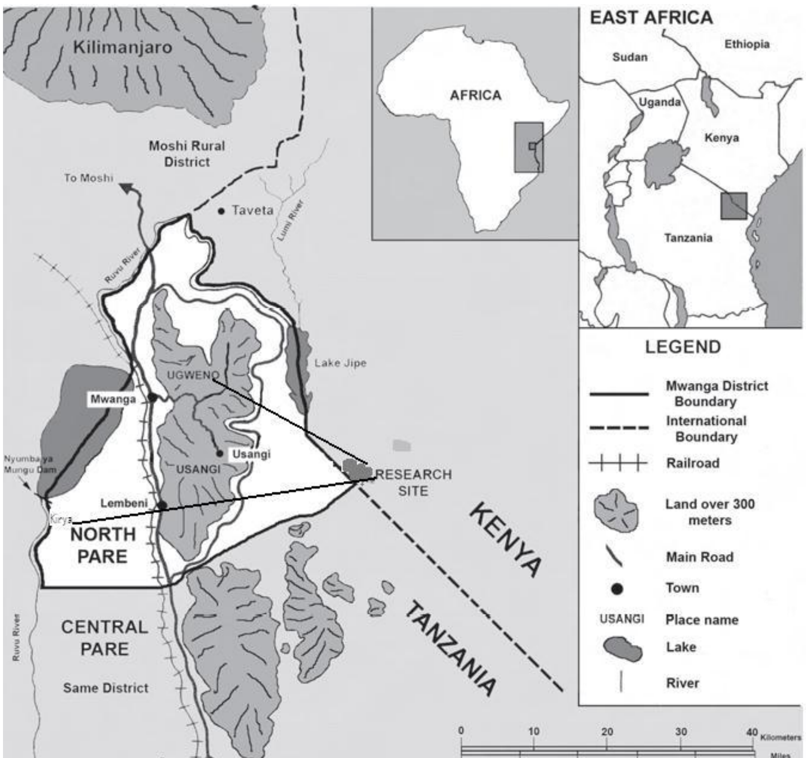

Fig. 1 Map of Mwanga District, Kilimanjaro Region, Tanzania (Source: [29])

B. Methods

Primary data were collected through Participatory Rural Appraisal (PRA) and households surveys with a random sampling of 103 households conducted purposively from three villages: Mangio, Lambo and Kirya. The household survey was undertaken using semi-structured questionnaire that included both open ended and closed questions, underlying, agroforestry (AF) and non-agroforestry practises, i.e., existing household size, practices, land size, number of planted tree, species name and use, AF products, income from AF and non-agroforestry and factors hindering sustainability of agroforestry.

Data was analysed using Statistical Package for Social Science (SPSS 16) to generate descriptive statistics. The generated frequency tables and chart were used in the interpretation of the results. Statistical means were used to compare socio-economic factors such as agroforestry income against non-agroforestry income. By using SPSS, inferential analysis was also carried out to predict whether or not the dependent (annual income) and independent (variety of crops, tree benefits, irrigation intervention, livestock products) variable was significantly related using linear regression model.

III. RESULTS

A. Trees Species Uses and Functions that Enhance Farmer's Adaptive Capacity

In the study area, agroforestry technologies involve agrosilvicultural (growing trees with crops), agrosilvopastoral (growing trees with pastures), agro horticultural, shifting cultivation and home garden (management of trees, crops and animals) were the main types of on-farm tree growing in the form of traditional agroforestry systems. The most frequent method of growing trees (except exotic trees and Coconut) was through deliberate retention and management of naturally regenerating tree seedlings. A total of 93 respondents were able to respond about types of tree species most preferred and planted or retained on their farms, and the answers are presented in Figure 2. Also result revealed that most of trees regenerated naturally, such as *Cordia africana*, *Croton macrostachyus*, *Markamia species*, *Acacia species* and *Albizia schimerana*. *Eucalyptus saligna* were reported as among the tree species which have higher return and low cost of management due to its sprouting characteristics. Also it was observed to be grown along steep slope, unfertile land and away from water source. Also Eucalyptus trees were reported to take a few years to be due to a number of its advantages and their adaptations to a wide range of ecological conditions. It was observed that farmers' willingness to grow trees on their farms was a function of their socio-economical, environmental and cultural factors. For example, farmers ignored trees which are incompatible with arable crops such as *Cedrella odorata* and *Acrocarpus fraxinifolius.* Farmers' perceptions have showed a strong relation to the positive outcomes of tree planting (see Table 1). Also farmers favoured importance of home garden as capital for future generations. From field survey it was observed that tree preference was a function of, security of land tenure, extension services, farmer's education level and past experience, for example retired people planted or retained larger number of trees in their farms.

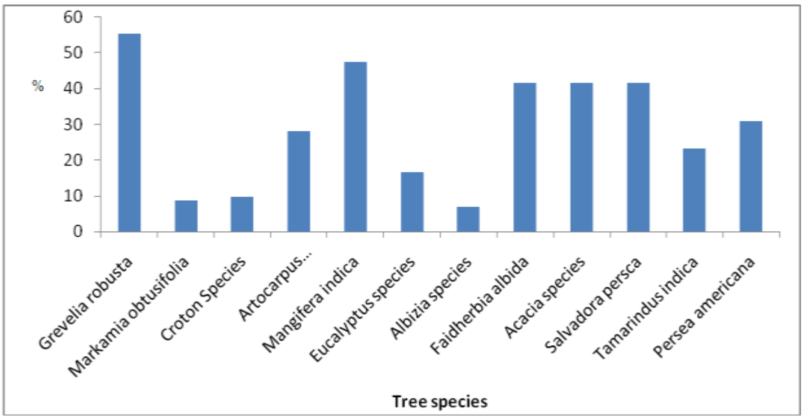

Fig. 2 Tree species that are resilience to climate variability

TABLE 1 LIST OF AF TREES SPECIES, USES AND FUNCTIONS THAT ENHANCE FARMER RESILIENCE

Species name	Uses/Functions
Grevellia robusta	Timber, shade, firewood, add organic matter
Cordia africana	Timber, shade, firewood, soil improvement, fodder
Tamarindus indica	Timber, Fruits, firewood, organic matter
Syzigium cordatum	Timber, fruits, firewood, organic matter, shade
Balanites aegyptica	Timber, firewood, organic matter
Markamia obtusifolia	Firewood, Fodder, Nitrogen fixation, shade
Croton Macrostachyus	Firewood, Fodder, Nitrogen fixation, shade
Kigeria africana	Fruits, shade, Nitrogen fixation
Eucalyptus saligna	Poles, firewood, wind break, erosion control
Acacia species	Firewood, Fodder, Nitrogen fixation, shade
Salvadora persca	Firewood, Fodder, Nitrogen fixation, shade
Cordia sinensis	Firewood, organic matter, shade
Ficus species	Firewood, shade, windbreak, control soil erosion

Albizia schemperana	Timber, firewood, nitrogen fixation, fodder ,rain indicator
Faidherbia albida	Firewood, nitrogen fixation, fodder, shade
Commiphora eminii	Firewood, fodder, shade, organic matter, support climber
Artocarpus heterophyllus	Fruits, shade, control soil erosion
Persea americana	Fruits, Firewood, shade, soil improvement
Mangifera indica	Fruit, erosion control, windbreak, firewood
Anona muricata	Fruits, shade, live fence
Anona squamosa	Fruit, shade
Croton megarocarpus	Firewood, shade, organic matter, control soil erosion
Syzigium guineense	Timber, firewood, shade, soil improvement
Azadirachta Indica	Firewood, shade, windbreak, control soil erosion
Psidium guajava	fruits, support climbers, firewood
Cocos nucifera	Fruits, windbreak
Rauvolfa caffra	Shade

Field survey, revealed that most of trees in agroforestry were used for fuel wood; other tree products obtained were also used for timber, fodder, shade, windbreak, poles, fruits, shelter, soil improvement and supporting climbers' crops (see Table 1).

Acacia species were reported to be a source of fodder for their livestock's; it was observed that pastoralist retained *Acacia, Balanite, S.persca* and *F.albida* in order to provide shelter from rain and wind, shade from the sun and cover from predators. These also protected new-born lambs, injured, old or sick animals. It was observed that tree was a function of gender of farmer, for example female preferred multipurpose trees for important reasons were tree products contributing to food, fruits, and shade during farm activities, fuel wood, soil fertility improvement and fodder. These trees included *Faidherbia albida*. Males preferred trees provide construction material and income. Result showed that most tree species in the study area were useful for fuel wood; hence increasing the resilience of natural forest e.g. eastern arc mountains (see Table 1). However not all agroforestry satisfied fuel wood for household, hence most of respondents reported to buy fuel wood from farmers with eucalyptus woodlots in order to satisfy their households need. They paid an average of TAS 10, 000 (6.3US$) per cubic meter and normally household size of 6 people in the study area spent an average of 9 m3 per year.

B. Roles of Agroforestry Products and Production in Increasing Farmer's Resilience against Climate Variability

From animals products farmers obtained organic manure and milk. Some respondents claimed that, cattle manure bring best effect on banana, coffee and maize growth, farmers placed first priority on manure rather than meat or milk. One respondent claimed to use sheep dung (fresh) in controlling nematodes in banana. From the household interviews, 33% of the respondents depended on *desmodium* spp and elephant grass to feed their livestock, 25.2% depended on elephant grass while only 22.3% depended on grassland. Furthermore, AF farmers were more beneficial than non-AF farmers, because they acquired additional money through selling poles and fuel wood and also saved money and time that could be used for buying or searching for fuel wood, fertilizers and fodders.

The household surveys revealed that majority of the respondents were not engaged with coffee production. The most important reasons given included drought, low price for the past decade and unavailability of agricultural subsidies. Most respondents obtained food products from maize, cassava, banana, paddy and yams crops. Cardamom and sunflower were among the new cash crops found to be grown in highland replacing coffee, respondents reported to prefer cardamom because of its good price. It was revealed that the price of one kilogram ranged between TAS 14000 to 25000 and one stem of cardamom could produce between 0.25kg to 3 kg per season depending on management practices. Furthermore, other respondents were involved in horticultural crops such as tomato, pepper, water melon and sweet melon. The main reasons motivated were crops contribution to household cash income and irrigation infrastructures.

A total of 59.2% of the surveyed households reported that yams, cassava and sweet potato were the main source of food during drought in the highlands compared to less adaptive crops such as maize, banana and rice as reported by 14.6%.

Further farmers were interviewed to identify their coping strategies during 2008 drought and 1997 flood. Results revealed that the first strategy used was through selling their livestock as reported by 71.8% of the respondents, 54.4% of the respondents reported to depend on agroforestry products such as fruits and 27.2% of the respondents depended on selling wood products such as timber and fuel wood. Another coping strategy in the highlands and lowland was bricks making and charcoal making as reported by 3.9% and 31.1% respectively. In total the contribution agroforestry products in buffering farmers during crops loss revealed to be high compared to other sources of income and food such as fishing reported by 9.7% in the lowland, labour work 56.3%, remittances 11.7% and food for work reported by 21.4%.

Inferential analysis was also carried out to predict whether or not the dependent and independent variable was significantly related using linear regression. Result from Table 2 revealed that independent variables were able to explain about 52% (R2=52%) variation in the dependent variable. The remaining 48% variations were due to omitted variables. Further the model revealed that irrigation intervention

(IGI) was statistically significant at $p < 0.001$ and positively correlated with the total income. On the other hand, Livestock product (LVP) was statistically significant at $p<0.01$ but influenced the total household's income negatively. This implies that increasing this variable at one unit will decrease total households income (resilience) as indicated with magnitudes of its coefficient.

TABLE 2 SIGNIFICANT TEST BETWEEN THE RESILIENCE AND COPING/ PRACTICES

Model	Unstandardized Coefficients		Standardized Coefficient		R^2=51.6
	B	Std.error	Beta (β)	t	Sig.
Constant	-845700.9	1.2		-0.699	0.487ns
Irrigation	1.9	219162.7	0.74	8.951	
Number tree				0.000***	
benefits	165919.9	261537.7	0.052		
Variety of				0.634	0.527ns
Crops	31575.5	135204.5	0.021		
Livestock				0.234	0.816ns
product	-317554.7	109212.4	-0.234		
				-2.908	0.005**

Not significant (ns) at P<0.05; Significant at **=P<0.01 *** =P< 0.001

The household surveys revealed that 98% of households interviewed were involved in livestock keeping. Among the animals frequently kept included goats, indigenous chickens, cattle, sheeps and donkeys. Goats were most preferred by 60.2% respondents because of the drought resistance followed by indigenous chicken which were preferred by 39.8% respondents. Respondents argued that browsing behaviour enabled goats to survive during shortage of grasses as compared to cows and sheeps which are grazers. However, most respondents reported to have less interest with hybrid (pure) breed cows because of their susceptibility to diseases and pests. Being a heave feeder, labour intensive and fodder selective were among reasons motivated farmer to ignore hybrid dairy cattle. However, majority of sampled households failed to admit their number of livestock owned. One respondent claimed that they hide information in order to avoid tax put by government, while other respondents argued that if you mention the number of livestock's you own all animals will die within a couple of days.

C. Income from Agroforestry as Farmer's Resilience to Climate Variability

Agroforestry techniques were reported to improve household's income through sale of timber, firewood, poles, fruits and non wood products. Farmers were interviewed on the amount of cash income they could earn through sale of these products. Comparable average of income and percentages of contribution for each product both AF and non AF farmers are presented Table 3.

TABLE 3 CASH INCOME GENERATED FROM AF AND NON AF (1 US$=1600TAS)

Products	Minimum	Maximum	Mean	Percent
AF income in (TAS)				
Selling tree for Timber	100000	200000	150000	1.7
Fruits from tree	30000	200000	90483.3	1.0
Coffee	35000	84000	59500	0.7
Banana	105000	2100000	731484	8.3
Rice	450000	2070000	1130625	12.8
Maize	30000	6000000	985714	11.2
Spice(Cardamom	60000	300000	154772	1.8
Milk	146000	2920000	382176	4.3
Tomato	1000000	3200000	2145833	24.4
Water or Sweet melon	1600000	4400000	2980000	33.8
Sum	**3556000**	**21474000**	**8810587.3**	
Non AF participant				
Maize	900000	4080000	1914545	24.5
Rice	1080000	1710000	1404000	17.9
Tomato	2300000	3200000	2840000	36.3
Water or Sweet melon	1040000	2400000	1664000	21.3
Sum	**5320000**	**11390000**	**7822545**	

Results from survey indicated that AF participants in Mwanga District in average had extra income than non-AF participants of TAS 98 8042.3 (US$ 617.5) annually). However, the contribution of each item to total cash household income or village is shown in Table 3 and 4.

TABLE 4 CASH INCOME OF AGROFORESTRY AND NON AGROFORESTRY FROM THREE VILLAGES

Village	Minimum	Maximum	Mean	St.Dev	Sum	N
AF income (TAS)						
Mangio	635000	3002000	1465866.7	607981.7	43976000	
Lambo	616000	1192000	943173.3	153132.8	3028295200	
Kirya	1190000	5810000	3072969.7	1342663.6	30101408000	
						33
Non AF income (TAS)						
Mangio	0	0	0	0	0	0
Lambo	0	0	0	0	0	0
Kirya	2520000	4700000	3185000	760471.3	31850000	10

Field survey revealed that in Kirya village agroforestry participant earned an average income of TAS 1 342 663.60 (US$ 839.2) annually, which was higher than any other village (see Table 4). This may be contributed by the types of crops which are grown and which includes paddy, maize and horticultural crops, and these crops were reported to fetch higher price. However, these estimates of agroforestry products exclude the income which farmers could earn or save from selling or buying fuel wood, fodder, livestock, medicine and cattle manure. Arable crops contributed about 92.9% for AF household incomes while livestock products (milk) contributed about 4.3% for AF household income.

Furthermore, agroforestry systems in the study areas revealed to face different challenges such as an increase surface temperature, changes in rainfall, fluctuation of river flows, land degradation and drought. Study showed that 76.7% of the respondents reported drought to affect soil moisture and water sources and 23.4% of the respondents reported increase in surface or soil temperature. Also the impact of drought was revealed to increase pests and diseases in crops as reported by 64.1% of the respondents, 20.4% reported drought to reduce crops yield while 15.5% of the respondents reported drought to cause wilting of the crops. Other impacts of drought were reported by livestock keepers, 65% reported drought to cause shortage of fodder and water, 11.7% reported drought to increase pests and diseases in livestock while 4.9% of the respondents reported loss of body weight as the impact of drought. Whilst all farmers interviewed revealed nematodes and mites to affect banana, coffee and horticultural crops production. However, field observation revealed that soil erosion and salinization were major challenges of agroforestry in the highland and lowland respectively, since land management practices such as contour, and terraces were not practiced by larger number of farmers.

IV. DISCUSSION

A. *Tree Uses that Increase Farmer's Resilience to Climate Variability*

Trees help to buffer subsistence farmers against environmental extremes by modifying temperatures, providing shade and shelter and acting as alternative sources of feed for livestock during the period of drought, as discussed in the previous section. These observations are consistent with other studies on the multifunctional role of trees by sustaining production during wetter and dry season [33]. References [39] and [34] showed that tree products and uses played an important role in responding to climate change and buffering subsistence farmers against crops loss. For example, [24] realized that multipurpose trees and shrubs are the mainstay of most traditional agroforestry systems, and its contributions reported to be grouped under two broad categories: production of commodities and ecosystems services. Similarly, [33] reported the multifunctional role of trees in their provision of resources for animals' in Elm Farm. Several studies revealed that if fodder for livestock will depend more on bushes or trees and less on grasses and annual grain crops, the risk of losses during floods, drought and landslides becomes less, because trees are more resilient to such weather conditions than other plants argued by [36].

As shown in this study and many other studies, adaptation responses to environmental changes often seem to be constrained by prolonged drought and land degradation that can jeopardize land productivity and threaten adaptive capacity of subsistence farmers [13]. This is exemplified by low productivity of land due to soil erosion, decline in soil fertility and increased salinity of the soil. However, [19] and [16] reported that trees such as *Acacia nilotica*, *Dalbergia sissoo*, *Terminalia arjuna* and *Salvadora persica* offer a cost-effective and promising option (phytoremediation) to reclaim large tracts of salts affected soil respectively. Certainly farmers are taking adaptive measure and with less understanding of the aforementioned benefits of tree products, and trees planting preferences in study area were shaped by socio-economic and environmental factors. For example, [28], [3], [24], [6] and [39] reported that tree planting was most associated with compatibility with other crops, easy to manage, higher income from off-farm employment opportunities and high level of awareness/ understanding of the importance of tree planting. Proximity to town was also observed to favour trees with higher return such as fruits trees, timber and poles. Competition with other crops motivated farmers to ignore planting *Cedrella ordorata* and *Acroarpus fraxinifolius* [41]. Whilst past experience had shown that avocado (*Persea americana*) and mango trees do well during drought hence people reported to depend on fruits during drought periods. Similarly, tree planting or retention were perceived by the larger number of their uses either for fuel wood, fodder, timber, fruits or income enhancement evidenced from Swat-Pakistan and Ethiopia respectively [17, 22].

B. Role of Agroforestry Products and Production in Increasing Farmers` Resilience to Climate Variability.

A variety of benefits of AF products found in this study are also similar to those found in other studies. Although in this particular study farmers put more emphasis on the benefits of shade, livestock manure, fodders and wood products. References, [6] and [30] argued the major role of agroforestry in adaptation to changing environmental conditions was through supporting the production of wide range of products including food, fuel wood, fodder and forage, timber, shade, gardening material, medicine, and ecological services. Reference [24] and [33] argued that agroforestry systems can be more useful in maintaining production during wetter and drier years. A central hypothesis in agro forestry is that productivity is higher in agroforestry systems compared to monoculture systems due to complementarities in resource-capture i.e. trees acquire resources that the crops alone would not. This is based on the ecological theory of niche differentiation; different species obtain resources from different parts of the environment, such as, tree roots of *Persea americana* and *Syzigium species* extend deeper than crop roots and are therefore able to access soil nutrients and water unavailable to crops, as well as absorb nutrients leached from the crop rhizosphere [33, 26]. In drought-prone environments, such as Rajasthan, as a risk aversion and coping strategy against climate variability, farmers maintain agroforestry systems to avoid long-term vulnerability by keeping trees as an insurance against drought and insect pest outbreaks [30].

Diversification of crops in agroforestry systems was among the coping strategy used by farmers to support them during drought, these involved intercropping more than three crops on the same piece of land, such crops included maize, paddy, cassava, sweet potato, sun flower, beans, horticultural crops, coffee, pineapple, yams, taro, nuts, sugarcane, passion crops and cardamom. Farmers applied also several techniques during flood, river flow changes or famine. These included cultivation in wetlands, using water pump for irrigation, crop rotation and grazing near water sources. Other coping strategies during crops loss involved selling of livestock in order to meet their basic needs, eating or selling fruits and roots crops, selling timber and fuel, bricks making and charcoal making. This finding agrees with other adaptation literature that suggested (multi-sectoral) products diversification in improving the resilience of farmers [10, 35]. Scholars suggest a variety of methods to improve farmers' adaptive capacity, including strengthening strategies that people developed, improving farm productivity, providing off-farm source of income, planting drought resistance crops and improving access to markets [20]. For instance, [16] argued *Salvardora persca* leaves and bark to contain the alkaloid and its seeds were rich in oil and contain organic acids which are potential for making soaps, candles, and using it will provide off-farm source of income in the study area.

In this study products diversification were observed not guarantee sustainable adaptation in term of securing basic need under climate change [11] since most people lack skills, labour, capital or information necessary for such specializations and policy support. Agroforestry has been proposed as potential strategy for helping subsistence farmers reduce their vulnerability to climate change through the intention use of tree in cropping systems to increase productivity, diversify income sources and improve environmental services [6, 31, 37]. Reference [30] argued that, even the trees that do not fix nitrogen can enhance physical, chemical and biological properties of the soils by adding significant amount of organic matter. In addition, trees can also reduce soil erosion by providing long- term vegetation cover. Maintenance and enhancement of soil fertility is vital for farm productivity and environmental sustainability [3]. Irrespective of motivation for adaptation, both purposeful and unintentional adaptations can generate short-term or long-term benefits [2], whilst what appears successful in the short term turns out to be less successful in the longer term. But trade-off [8] exist such as competing claims on natural resources access and uses which become increasingly acute, with subsistence farmers becoming more vulnerable to adverse outcomes of such competition. Reference [14] suggested competing claim approach as a more equitable, management options that will reduce rural vulnerability for achieving sustainable adaptation to climate variability. The approach [14] will enable communities in addressing competing claims on natural resources that involve complex situations where uncertainty is high and where different values and interests are at stake. The approach in this sense can be useful in three ways: as an analytical tool to better understand today`s challenges of resources access and use, unsustainable resource exploitation, land degradation and vulnerability. Secondly, the approach offers a management tool to make the competing claims of stakeholders visible, manage emerging conflicts better by not neglecting stakeholder's power dynamics. Thirdly, as a tool to trigger innovation in resources use and production: finding new ways to reduce subsistence farmers` vulnerability to climate change.

C. Income from Agroforestry in Increasing Farmer's Resilience.

Studies on agroforestry systems have shown that financial benefits are the results of increasing the diversity and productivity of the systems which are influenced by market and price fluctuations of wood products, livestock and annual crops [33]. For instance, cash income of AF participants in Mwanga District earned an average extra income than non-AF participants of US$ 617.5 annually. This finding was lower than that reported by [21] of US$ 760 in semi arid areas of Misungwi district, Tanzania. While the income obtained from agroforestry in Kenya was lower, for example, lower Nyando farmers involved in agroforestry project earned an average, between US$ 19-137 [35]. In northeast India an average net monetary benefit acquired from guava based agroforestry systems was US$ 448 and US$ 300 to Assam lemon based agroforestry systems per hacter [30]. These differences in incomes between farmers from semi-arid areas and higher potential areas may be contributed by the factors like AF systems and technologies adopted, number or type of trees species and crops established and sold, markets price of agroforestry products, land size, age of the trees and bargain power of farmers. Similarly, [26] argues household income from rice field in Central Indian upland provides an illuminating economics with a variety of products , including fuel wood (30kg/tree), small timber for furniture (0.2 m3), and non timber product. Tree accounted for nearly 10% of the annual farm income-distributed uniformly throughout the year.

According to reference [13] from his study on the role of agroforestry and achievement of the Millennium Development Goals argued that enhanced tree based system and improved tree product marketing have a potential to reduce farmers vulnerability to climate variability. Although, lack of market price transparency, and inadequate of processing techniques to add value to agroforestry products increase farmer vulnerability under climate change and variability. This is exemplified by poor market policy of agroforestry products like fruits and spoilage of perishable tree products. Several literatures revealed the potential of non timber forest products (NTFPs) in improving resilience of subsistence farmers against climate variability, but vigorous efforts are needed to provide knowledge on the on-farm value addition innovation. For instance, [25] reported that processing of both exotic and indigenous fruits enabled 85% of women in Tabora, Tanzania to generate income through processing and selling juice, jam and wine. Women earned an average of US$ 9 per week through selling of juice, US$ 13 through selling of wine. While 17% of women from Shinyanga,Tanzania earned an average of US$ 7 per week through selling jam. The most used tree species included *Vitex species, Adansonia digitata, Syzygium guineense, Psidium guajava, Carica papaya, Mangifera indica* and *Passiflora edulis.* The extra money earned was used for meeting other basic need needs s such as education, buying food and other asset. References [27] and [13] argue that, tree based systems if supported by appropriate cultivation, processing and marketing methods, agroforestry products can make a major contribution of the economics development of the millions poor farmers by meeting their basic needs for food, fuelwood and income. Location base finding revealed to contribute a great variation on agroforestry production. Agroforestry participants in lowland earned an average income of TAS 1342 663.60 (US$ 839.2) annually, which is higher than any other villages , due to the types of crops which are grown such as paddy, maize and horticultural crops, reported to fetch higher price. For example, the price of 100kg of maize and rice reported to be TAS 60 000 and 70 000 (US$37.5 & 43.8) respectively. Availability of irrigation infrastructures in this village enabled farmers to cultivate throughout the year contrary to other villages which depended on rain-fed agriculture. Similarly Reference [35] in Western Kenya argued that location had a significant impact on farm productivity and household wealth.

Moreover, exposure, disease and pest (such as nematode and mites), sensitivity and adaptive capacity are evident at community or local levels and a driver that influences local level vulnerability [9].This is exemplified by poor road network and market, resource depletion ,poor access of social needs like clean and safe water and extension services. Also farmers in the lowland rely on irrigation water captured in a river. A very wet or dry year, far beyond the normal conditions, may lead to water intake failure, thus the main coping range cannot be returned to in a subsequent year. In Phillipines, root extract from *Leucaena leucoephala* were highly effective against eggs nematodes eggs hatching and infestation [38]. The performance of this root extra was comparable to that of chemically based nematicides, and the antinematicidal compounds of plant could be used for nematode management complementing synthetic nematicides [38, 42, 43]. Also leaf extra or bulb extract from garlic (*Allium sativa*) and onion (*Allium alia*) were more effective against [38]. Nevertheless, our finding revealed sheep dung (fresh) where highly effective against banana nematodes, and there is a need for scientific data to support these practise. According to [40], the regular use of miticides was reported to kill predatory mites or create pest resistance in the plant, however, soft chemical spray such as petroleum oil and potassium soap was reported to be effective in controlling certain species of mites in crops.

V. CONCLUSION

This study described the potential of agroforestry in increasing resilience of subsistence farmers who are different in altitudinal range and climatic conditions. Agroforestry systems reflected diversity in terms of the multiple benefits from trees, crops and livestock integrated in agriculture systems. Agroforestry products improved resilience of smallholder farmers against climate changes, particularly by improving farm production (food, fodder, timber, fuel wood, and manure), ecosystem services (soil improvement, climate amelioration, wind break, erosion control, and disease and pest control) and household income. Agroforestry practitioners were economic resilient that enabled to resist against stress, disturbance, shock and perturbation than those who depended on conventional agriculture. Although farmers are not materially poor and products diversification is still new to some farmers because of inadequate skill, information, knowledge and agro forestry policy, we can conclude:

(1)Effective extension services, training, agroforestry policy and outreach programme in order to enhance farmer`s agroforestry practices with primacy to multifunctional values of AF such as using extract from garlic, sheep dung and *Leucaena leucocephala* in controlling mites and nematodes, fodder, soil improvement;(2) Maintenance of the traditional agroforestry systems and strategic creation of new systems such as beekeeping and aquaculture in rice farm;(3)Promoting existing new cash crops like passion fruits, sunflower, cardamom and sweet melon that are useful in improving household income.

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REFERENCES

[1] N. Adger, D. Moran, and A. Wreford, “Climate change and Agriculture: impacts, adaptation and mitigation,” Organization for Economic Co-operation and Development (OECD), p. 140, 2010.

[2] W.N. Adger, N. W. Arnel and E.L. Tompking, “Successful adaptation to climate change across scales,” *Global Environmental change.,* Vol. 15, pp. 77-86, Dec. 2004.

[3] O.C. Ajayi, F. Place, K.F. Akinnifesi and W.G. Sileshi, G. W, “Agricultural success from Africa: the case of fertilizer tree systems in southern Africa Malawi, Tanzania, Mozambique, Zambia and Zimbabwe,” *International journal* of *agricultural sustainability.*, Vol. 9, pp. 126-136, 2011.

[4] L. Berrang-Ford, J.D. Ford and J. Paterson, “Are we adapting to climate change,” *Global Environmental Change.,* vol. 21, pp. 25–33, October. 2011.

[5] A. Colls, N. Ash and N. Ikkala, *Ecosystem-based Adaptation: a natural response to climate change*. Gland, Switzerland: IUCN, p. 20, 2009.

[6] H.N.de Souza, J. de Graaf and M.M. Pulleman, “Strategies and economics of farming systems with coffee in the Atlantic Rainforest Biome,” *Agroforestry systems.,* Vol. 84, pp. 227-242, Nov., 2011.

[7] N. Doggart, C.Leonard, A.Perkin, M. Menegon and F. Rovero, “The vertebrate biodiversity and forest condition of the North Pare mountains,” Tanzania Forest Conservation Group (TFCG). DSM, Tanzania. Technical paper No. 17, 2008.

[8] S. Eriksen, P. Aldunce, C.S. Bahinipati, R.D. Martins, J.I. Molefe, C. Nhemachena, K. O``Brien, F. Olorunfemi, J. Park, L. Sygna and K. Ulsrud, “When not every response to climate change is a good one: Identifying principles for sustainable adaptation,” *Climate and Development.,* Vol. 3, pp. 7-20, 2011.

[9] S. Eriksen, T.R.J. Klein, K. Ulsrud, O.L. Nass and K. O’Brien, “Climate change adaptation and poverty reduction: Key interactions and critical measures,” Report prepared for the Norwegian Agency for Development Cooperation (NORAD). Oslo: University of Oslo, p. 44, 2008.

[10] S. Eriksen, K. O’Brien and L. Rosentrater, “Climate change in Eastern and Southern Africa. Impacts, vulnerability and adaptation,” Report prepared for the Norwegian Agency for Development Cooperation (NORAD). Oslo: University of Oslo, p. 27, 2008.

[11] S. Eriksen and K.L. O’Brien, “Vulnerability, poverty and the need for sustainable adaptation measures,” *Climate policy.,* vol. 7, pp. 337-352, 2007.

[12] S.E.H. Eriksen, R.J.T. Klein, K. Ulsrud, L.O. Naess and K. O’Brien, “Climate change adaptation and poverty reduction: Key interactions and critical measures,” Report prepared for the Norwegian Agency for Development Cooperation (NORAD). Oslo:University of Oslo, p. 44, 2007.

[13] D.P. Garrity, “Agroforestry and the achievement of the Millenium Development Goals,” *Agroforestry systems.,* vol. 61, pp. 5-19, 2004.

[14] K.E. Giller, C. Leeuwis, J.A. Andersson, W. Andriesse, A. Brouwer, P. Frost, P. Hebinck, I. Heitkönig, M.K. van Ittersum, N. Koning, R. Ruben, M. Slingerland, H. Udo, T. Veldkamp, C.van de Vijver, M.T. van Wijk and P. Windmeijer, “Competing Claims on Natural Resources: What role for Science*?”, Ecology and Society.,* vol. 13, pp. 1-18, 2008.

[15] C. Hemp and A. Hemp, *The Chagga Homegarden on Kilimanjaro*. Diversity and refuge function for indigenous fauna and flora in anthropogenically influenced habitat in tropical region under global change on Kilimanjaro Tanzania, p. 6, 2008.

[16] D.A. Hines and K. Eckman, “Indeginous multipurpose trees of Tanzania: Uses and economics benefits for people”, Forestry Department FAO, Rome p. 285, 1993. http://www.fao.org/docrep/X5327e/x5327e00.htm#Contents.

[17] M. Irshad, A. Khan, M. Inoue, M. Ashraf and H. Sher, “Identifying factors affecting agroforestry in Swat, Pakistan,” *African Journal of Agricultural Research*., vol. 6, pp. 2586-2593, April, 2011.

[18] Z. Kebebew and K. Urgessa, “Agro forestry perspective in land use pattern and farmers copying strategy: Experience from Southwest Ethiopia,” *World journal of Agricultural science.,* vol. 7, pp. 73-77, 2011.

[19] B.M. Kumar, “Agroforestry: The new old paradigm for Asian food security,” *Journal of Tropical Agriculture.,* vol. 44, pp.1-14, 2006.

[20] B.B. Lin, “Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change,” *BioScience.,* vol. 61, pp. 183-193, 2011.

[21] S.M. Maduka, “Role of Agroforestry products in Household income and poverty reduction in semi-arid areas of Misungwi District, Mwanza Tanzania,” Master of Science in Forestry of Sokoine University of Agriculture, Morogoro, Tanzania, Nov.2007.

[22] Y. Moges, “Eucalyptus Trees and the Environment: A new perspective in times of climate change”, in *Proceedings from the Congress held in Addis Ababa. September 15th-17th, 2010,* pp. 104-113.

[23] P.K.R. Nair, B.M. Kumar and V.D. Nair, “Agroforestry as a strategy for carbon sequestration,” *Journal of Plant Nutrition. Soil science.,* vol. 172, pp. 10-23, May. 2008.

[24] R.K. Nair, “Agro ecosystem management in 21st century: It is time for a paradigm shift,” *Journal of tropical agroforestry.,* vol. 46, pp. 1-12, Dec. 2008.

[25] P.A. Oduol, G.Nyadzi, R. Swai, M. Schueller, B. Gama, S.Matata, W.Mwageni, D.W. Mbaruku, “Adoption and Impact of Agroforestry Technologies on Rural Livelihoods in Southern Africa,”in proceeding of the second National Agroforestry and Environment Workshop Mbeya, Tanzania 14-17th March 2006.

[26] D.N. Pandey, “Multifunctional agroforestry systems in India; CIFOR, Bogor, Indonesia,” *Current science.,* vol. 92, pp. 455-463,Feb.2007.

[27] KPC. Rao, L.V. Verchot and J. Laarman, “Adaptation to Climate Change through Sustainable Management and Development of Agroforestry Systems”, World Agroforestry Center. *ejournal.icrisat.org.,* vol. 4, pp.1-30,Dec.2007.

[28] T. Reyes, *Agroforestry and Gender sensitive agribusiness as tool to climate change adaptation*. A case study from the Usambara

Mountains Tanzania, pp. 15, 2011.

[29] M.J. Sheridan, "The Environmental and social History of African Sacred Groves: A Tanzania Case study," *African Studies Review.*, vol.52, pp.73-98, 2009.

[30] S.V. Singh and D.N. Pandey, *Multifunctional Agroforestry Systems in India: Science-Based Policy options*. Climate change and CDM Cell Rajasthan State Pollution Controll Board, p.35, 2011.

[31] B. Smit and J. Wandel, "Adaptation, Adaptive capacity and vulnerability," *Global Environmental Change.*, vol.16, pp. 282-292, 2006.

[32] R. Smit, Burton, T.J.R. Klein and J. Wandel, "An anatomy of adaptation to climate change and variability", *Climate Change*., vol.45, pp. 223-251, 2000.

[33] J. Smith, *Agro forestry: Reconciling production with protection of the environment*. A synopsis of Research literature. Organic Research Centre. Elm Farm, p.24, *2010.*

[34] D.J. Snelder, M. Klein and S.H.G. Schuren, "Farmers' preferences, uncertainties and opportunities in fruit-tree cultivation in Northeast Luzon," *Agroforest Syst.*, vol.71, pp. 1–17, July.2007.

[35] T. Thorlakson, "Reducing subsistence farmers` vulnerability to climate change: the potential contributions of agroforestry in western Kenya", Occasional Paper Nairobi: World Agroforestry Centre, paper 16. P. 76, 2011.

[36] K. Ulsrud, L.Sygna and K. O`Brien, "More than Rain: Identifying sustainable pathways for Climate adaptation and Poverty Reduction'. Published by Development Fund, Norway, p. 68, 2008.

[37] L.V. Verchot, A. Albiecht, S. Kandji, M.V. Noordwijk, T. Tomich, C. Ong, J. Mackensen, C. Bantilan, K.V. Anupama and C. Palm, "Climate change linking adaptation and mitigation through agroforestry", *Mitig Adapt Strat Global change.*, vol.12, pp. 901-918, April, 2007.

[38] D. Waele and R.G. Davide, G.R, The Root-Knot Nematodes of Banana. Musa Pest Factsheet No.3. 1998.

[39] R.J. Zomer, A. Trabucco, R. Coe and F. Place, "Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agro forestry," ICRAF Working Paper no.89. Nairobi Kenya:World Agroforestry Center, paper, 2009, paper 89, p.72.

[40] L. Zhang, Biological and pest Management of Spider mites. Factsheet. Northern Territory Government, 2008

[41] C. Orwa, A. Mutua, R. Kindt, R. Jamnadass and A. Simons, (2009). Agroforestree Database: tree reference and selection guide version 4(http://www.worldagroforestry.org/af/treedb/)

[42] O.K.Adekunle and M.N. Aderogba, "Characterisation of an antinematicida compound from leucaena leucocephala", *Australian plant disease Note.*, vol. 3, pp. 168-170, 2008.

[43] O.K Adenkula and A. Akinlua (2007). "Nematicidal effects of *Leucaena leucocephala* and *Gliricidia sepium* extracts on *Meloidogyne incongita infecting okra", Journal of agricultural sciences.,* vol. 52, pp. 53-63, 2007.