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Feasibility of buffer zone agroforestry farming practices in the conservation of mangrove ecosystems: A case study assessment from some local communities in Central African coastal zone, South Western Cameroon

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Abstract

Mangroves (stretch of intertidal tropical and subtropical forests between inland coastal forests and the sea) are being exploited at a rate that is unprecedented, there is loss of biodiversity because of conflicting and unsuitable uses. This study was aimed at promoting the protection of mangrove and associated coastal forests within Tiko and Limbe III municipalities in south western Cameroon, Central Africa via the contribution of buffer zone agroforestry. Representative traditionally dominant agricultural land use sites were surveyed for the identification and analysis of farming practices using participatory rapid appraisal (PRA). Data collected (qualitative and quantitative) were subjected to descriptive and inferential statistics. Out of twelve (12) agroforestry practices currently carried out by farmers under three widely dominant classic agroforestry systems (agri-silvicultural – plantation and non-plantation, silvo-pastoral and agri-silvo-pastoral systems), 5 of them under plantation and non-plantation systems (palms on crops lands, cocoa-based, rubber on crop lands, scattered trees on farmland and home gardens) were considered climate smart agroforestry practices. The maximum diameter, density, height and crown diameter of trees were dominant in the cocoa-based except for the mango-based which had the maximum tree height. The tree size class for poles (≥10cm to <30cm) was dominant in the 5 practices. For a more inclusive green economy and climate smart agriculture, some improvements on tree density, shade management and choice of multi-purpose trees species (*Cedrela sepium, Moringa oleifera, Leucaena leucocephala* and fruit trees) for vital functions such as firewood, soil improvement, medicine, food and construction are advocated to enhance sustainable exploitation of adjacent coastal forests thus protecting mangrove. Moreover, on account of resultant stable tree species, structural and use diversity of adjacent coastal forests, further make buffer agroforestry to hold promise for the conservation of fragile and vulnerable mangroves. There is therefore also need to expand the present study in other mangrove areas especially the mangroves of Cameroon Estuary which is the major deforestation hotspot in Cameroon.

Keywords: Buffer zone Agroforestry; Agroforestry systems and practices; Climate smart Agroforestry; Conservation; Sustainable management; Cameroon

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1. Introduction

Reports abound [1,2,3] pointing to the fact that mangroves (stretch of intertidal tropical and subtropical forests between inland coastal forests and the sea) are one of the most productive terrestrial ecosystems in the World and are a natural, renewable resource. In most countries these coastal wetlands are protected under different legal systems, in the case of Cameroon under Forests, Wildlife and Fisheries (1994) and Enviromental (1986) laws [4, 5]. These mangroves provide wide range of resources and ecosystem services for human livelihoods, including: fisheries production; timber production; coastal protection; pollution abatement; and carbon sequestration. Their primary production supports numerous forms of wildlife and avifauna as well as estuarine and near-shore fisheries. Several reviews are dedicated to mangrove forests, addressing their global distribution ecology, biology and value /uses [6,7,8,9,10,11,12,13,14,15]. Despite our improved understanding of the importance of mangrove forests and their ecosystem services, negative perceptions of these intertidal coastal-marine wetlands are still common.[16]

Unfortunately due to poverty and search for survival the resources of these very valuable ecosystems are exploited at unsustainable rates leading to rapid conversion and degradation of the mangrove ecosystems. The degradation of mangrove forests not only depletes the resources within their boundaries, but also affects the productivity of the adjacent coastal and marine ecosystems and is a cause of serious environmental and economic concern to many developing countries including Cameroon.

Agriculture is the backbone of economes of these countries and can help mitigate climate change through reducing emissions from the agricultural sector and pressure on surrounding forests by investing in agroforestry practices that provide fuel wood, reducing the need to deforest. However, not all agroforestry practices are viable everywhere.

The introduction of agroforestry practices into buffer zones around protected forest areas has been suggested as a technology option which may not only reduce pressures on forest reserves but which also can improve the living standards of the rural population living around these protected areas [17]The main objective of this work to promote the sustainable management of mangrove and associated forests within some local communities (Tiko and Limbe III municipalities) with 34 villages via the contribution of buffer zone agroforestry with specific objectives: (a) to identify and characterize the existing dorminant agroforestry practices within these local community mangrove and coastal forest ecotone; (b) to evaluate the climate smart potentials of these agroforestry practices; and (c) to select to henceforth promote suitable climate-smart agroforestry practices to meet the needs of buffer zone agroforestry.

We also hypothesised mainly that buffer zone climate smart agroforestry practices are socially accepted farming systems with high potentials to reduce degradation of mangroves and associated coastal forests. Other subhypotheses include (a) there is a high diversity (species richeness) of agroforestry practices within the local community farms of Tiko and Limbe III municipalities with limited potentials to reduce pressure on mangrove and coastal forests; (b) the structural composition of existing agroforestry practices limit the provision of ecosystem services (special diversity, production of fuelood/energy and carbon sequestrion); and (c) some agrofrestry practices are widely practiced and prefered to exhibit a high potentials for adoption for buffer zone agroforestry.

2. Material and methods

2.1. Presentation of study zone

The two councils (Figure 1) are important coastal areas within the South West Region of Cameroon. Tiko has 20 village comminities while Limbe III has over 14 village communities with a total population of 1,384,286 inhabitants with 4 key village communities practicing various forms of farming: Bonagombe, Bonabile, Mondoli an Dikolo and 10 other mangrove creek towns: Mabeta, Moboko I, Moboko II, Ijaw Mabeta, Kanye, Mboma I, Mboma II, Bimbia, Ijow Mboko and Iselele. Whereas Tiko council is an old council, Limbe III has just been created from the Limbe I city council. The project covers an area of 38,666 ha with a land use zoning and area coverage grouped into 3 zones: core zone of 10012 ha (25.89%); 12 817ha (30.56%) for the buffer zone and for agricultural zone of 16 838ha (43.55%). Over a total of 16 (47%) of the 34 village communities practicing various forms of agroforestry spread within the core, buffer zone and agricultural zone were survyed as follows: core zone, 3 villages (Mboko 1, Mboko11 and Bwenga); buffer zones, 6 villages (MabetaI, MabetaII ,Missellele,Tongo zone, Mondoni and Njuki); and 7 villages (Chopfarm, Bonalikomba, Mbimbia forest, New Ombe, Likumba and Ebonji) in the peripheral or buffer zone. Under the three agroforestry systems identified in these surveyed areas were the following distribution of 12 dominant agroforestry practices: agri-silvicultural (plantation and non-plantation) systems of 9 practices (live fence, home gardens, cocoa based, oil palm-based, scattered trees on farm land, mango-based, rubber-based, eru-based and *Cedrela*- based) 2 practices of silvo-

pastoral systems like live fence with animal, and fodder bank and 1only common practice of agro-silvo-pastoral system (home gardens and animals) (see Figure 2). Secondary data were collected from the Library of the Department of Forestry in the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang; Cameroon Wildlife Conservation Society (CWCS); Divisional Delegations of Forestry and Wildlife ; Fishery, Livestock and Animal Husbandry; Environment, Nature Protection and Sustainable Development; Tourism; Limbe III and Tiko Council, and the Internet [18]. These were used to design the pilot survey used to collect information on selected villages for easy identification and characterization of the agroforestry practices. The eventual selection of agroforestry practices for assessment was through a combination of sampling approaches. Purposive and quota sampling so as to have an equal representation of the agroforestry practices among the farmers to be sampled and targeted;

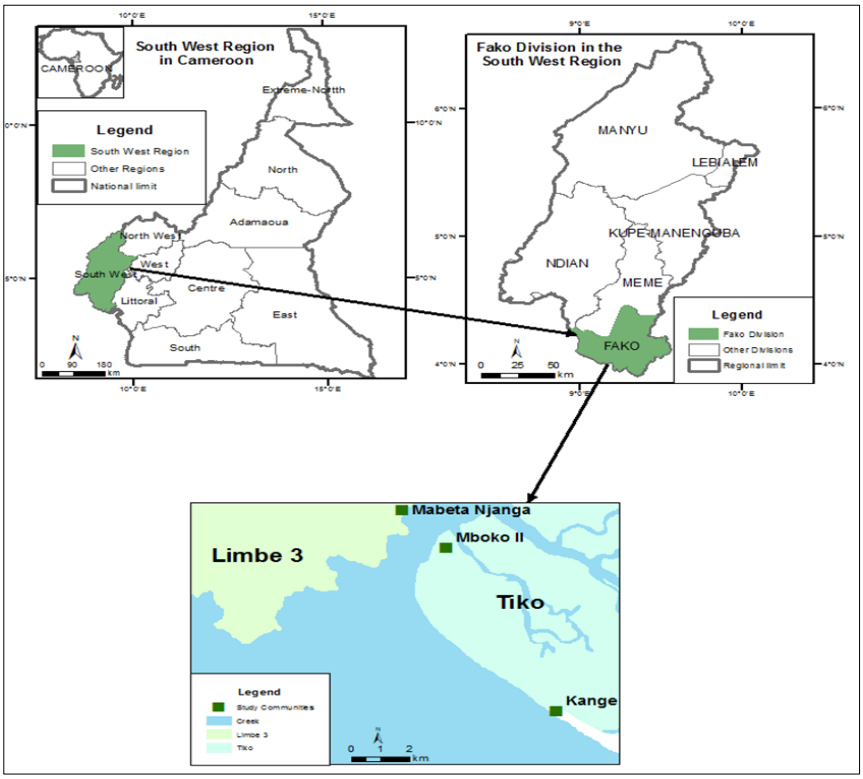

Figure 1 Location of the project area within South Western Cameroon

targeted random sampling scheme for the selection of farms that fell under targeted agroforestry classes in the area and various agroforestry practices according to availability of them. A total of eighty five (85) farms with twelve (12) different dominant agroforestry practices was eventually retained. The participative rural appraisal (PRA) approach [19] with topical qestionnaire (Appendix 1) was then used to collect socioeconomic data on the retained practices. The close and semi-structure questionnaire facilitated answer of the questions that addressed the specific objectives and hypotheses of the study including population's perception on their farming system (agri-silvicultural systems, silvo-pastoral systems and agro-silvo-pastoral system), where the respondents were mainly children, women and men. We also used stratified randon sampling (farm trees according to six diameter classes: Class one (1) being the lowest class diversity and Class five (5) the highest [2]) for farm parameters measurement where about 10 trees largest were identified and measured according to the class size diameter [20] including counting the rest of trees. The diameter of the trees was measured at the height of 1.3m above ground level (diameter at breast height) using the diameter tape, for small trees 5cm and above and calliper for smaller trees below 5cm [20]. `

2.2. Data Analysis

Data collected (qualitative and quantitative) were inserted into SPSS version 17.0 and Microsoft Excel 2007 were subjected mainly to descriptive statistics (frequency tables, graphs and %) in order to identify dominant farming systems, which address social, economic and ecological dimensions. Tree and stand parameters (e.g. basal area, volune, biomass, carbon content, etc) were estimated following standard forest mensuration procedures [20]. Species richness was also evaluated in the different agroforestry farms.

3. Results and discussion

3.1. Identification and characterization of the existing agroforestry practices

3.1.1. Structural identification of the agrofrestry systems and practices

Table 1 Trees identified and their uses on agroforestry farms of local communities of Tiko and Limbe III municipalities in South Western Cameroon

No.	Tree/uses	Scientific Name	fw	wb	pl	Fd	Sh	Ftr	lf	cop	com	Si	me	es	Total	(%)
1	Cedrela	*Cedrela sepium*	x	x	-	-	X	x	x	x	x	-	x	-	8	66.7
2	Mango	*Magnifera indica*	x	-	-	-	X	-	x	x	x	-	X	-	6	50.0
3	Pear	*Persea americana*	x	-	-	X	-	-	x	x	x	-	x	-	6	50.0
4	Moringa	*Moringa oleifera*	-	-	-	x	-	-	x	x	x	x	x	-	6	50.0
5	Guava	*Psidium guava*	x	-	-	X	-	-	-	x	x	-	X	-	5	41.7
6	Orange	*Citrus limonium*	x	-	-	X	-	-	-	x	x	-	X	-	5	41.7
7	Kola	*Cola acuminata*	x	-	-	-	X	-	-	x	x	-	x	-	5	41.7
8	Yellow quinine	*Anickia chlorantha*	x	-	-	-	-	-	-	x	x	-	x	-	4	33.3
9	Lemon	*Citrus limonium*	-	-	-	X	-	-	-	-	x	-	X	-	3	25.0
10	Bush mango	*Irvingia gabonesis*	-	-	-	X	-	-	-	-	x	-	x	-	3	25.0
11	Rubber	*Hevea brasiliensis*	x	x	-	-	-	-	-	-	x	-	-	-	3	25.0
12	Njasang	*Ricinodendron heudelotii*	-	-	-	X	-	-	-	-	x	-	x	-	3	25.0
13	Cocoa	*Theobroma cacao*	-	x	-	X	-	-	-	-	x	-	-	-	3	25.0
14	Bamboo	*Bambusa vulgaris*	x	-	x	-	-	-	-	-	-	x	-	-	3	25.0
15	Cedrela	*Cedrela odorata*	x	-	-	-	-	x	-	-	x	-	-	-	3	25.0
16	Umbrella tree	*Musanga cecro pioiodes*	x	-	-	x	X	-	-	-	-	-	-	-	3	25.0
17	Small leaf	*Piptadentum africana*	x	x	x	-	-	-	-	-	-	-	-	-	3	25.0
18	Mbanga school	*Terininalia catarpa*	x	-	x	-	-	-	-	x	-	-	-	-	3	25.0
19	Iroko	*Milicia excelsa*	x	-	x	-	-	-	-	-	-	-	-	-	2	16.7
20	Sapelle	*Entandronphragma cylindricum*	x	-	x	-	-	-	-	-	-	-	-	-	2	16.7
21	Mahogani	*Swietenia mahogany*	x	-	x	-	-	-	-	-	-	-	-	-	2	16.7
22	Country onion	*Afrostyrax lepidophyllus*	-	-	-	x	-	-	-	-	x	-	-	-	2	16.7
23	Flame of forest	*Monosperma kuntze*	-	-	-	-	-	-	-	-	-	-	x	x	2	16.7
24	Iroko	*Chlorohpll excelsa*	x	x	-	-	-	-	-	-	-	-	-	-	2	16.7
25	Boma tree	*Ceiba pentandra*	x	-	x	-	-	-	-	-	-	-	-	-	2	16.7
26	palm	*Elaeis guineensis*	x	-	-	-	-	-	-	-	-	-	-	-	-	8.3
27	Coconut	*Cocos nucifera*	-	-	-	X	-	-	-	-	-	-	-	-	1	8.3
28	Lead tree	*Leucaen leucocephala*	-	-	-	-	-	x	-	-	-	-	-	-	1	8.3
Frequency of uses amongst all species			19	5	7	11	4	3	4	9	15	2	12	1	-	-
%			67.9	17.9	25.0	39.3	14.3	10.7	14.3	32.1	53.6	7.1	42.9	3.6	-	-
Rank			1	7	6	4	8	10	8	5	2	11	3	12	-	-

fw: fuelwood wb: wind break, pl: poles fd: food, sh: shade lf: live fence cop:coppice com: commercial si :soil improvement me: medicine es: esthetics

The trees planted/retained are exploited for the following purposes: timber (28%), firewood (22%), shade (2%), windbreak (2%), soil fertility restoration (5%), medicinal (10%), food (26%), poles (2%) and live fences (2%). Farmers therefore cut down trees mainly for timber (used in the construction of houses) and for firewood (see Table 2).

Fifteen percent (15%) of farmers cut mangroves mainly to smoke fish, while the others (75%) use mangrove as firewood and for construction. Trees found on farmers' fields at mangrove interface constitute problems such as shade (80%), source of pests and diseases (3%), source of dirt (7%) and attraction to thieves (3%). The energy consumption by council illustrating the high dependence of rural communities on wood energy.

There were about 18 associated crops to tree species including white pepper, green pepper, bitterleaf, plantain, cocoyam, pineapple, maize, cassava, okra, yam, waterleaf, water melon, sweet potato, pumpkins, amaranthus, groundnut, melon and coconuts, cultivated either for home consumption, commerce or both. Farmers own between 1 and 14 farms, with a mean of 7 farms and standard deviation of 1.25 farms. To improve soil fertility, less than half (48%) of the farmers surveyed use fertilizers (mineral or organic), with N-P-K 20-10-10 being the most frequently (21%) used mineral fertilizer. The use of inorganic pesticides is higher (64%). The cropping calendar runs from January to December depending on the crop type. Because farmers grow many different crops on the same or different farms, they are fully employed all year round.Crops that can be grown twice a year, e.g. groundnut, maize and beans and crops grown once a year. Farmers receive information on agriculture from at least 7 sources, namely: media, friends, delegation of agriculture, meeting groups, NGOs, councils and others. More than half of them did not receive any formal training on good agricultural practices. The role of councils in disseminating agricultural information is very weak. The same is true with the different delegations of agriculture, who have the mandate to accompany farmers on the field. This may explain why adoption of good agricultural practices by farmers is low.

3.1.2. Characteristics of agroforestry systems

Twelve (12) agroforestry practices were identified, more prominent were: cocoa-based (26.1 %); Eru-based (2.13 %), Fodder banks (0.57 %), home garden (10.67 %), Live fence (19.91 %), Live fence (7.38 %) Mango-based (2.84 %), palm-based (12.2 %), Rubber-based (0.71 %), Scattered trees on farmlands (14.4 %) and Cedrela-based (0.85 %).

	
Cocoa-based	Cedrela-based
	
Fodder bank	Rubber- based

Palm-based

Gnetum and Gliricidia growing alongside trees

Figure 2 Some identified agroforestry practices on farms of local communities of Tiko and Limbe III municipalities in South Western Cameroon

These agroforestry practices inlude rubber, cocoa, palm and mango-based collectively described as plantation based agroforestry systems. The dominant agroforestry pratices are cocoa-based, home gardens, live fences, scattered trees on farmlands and palm-based agroforestry practices amongst others (Figure 3).

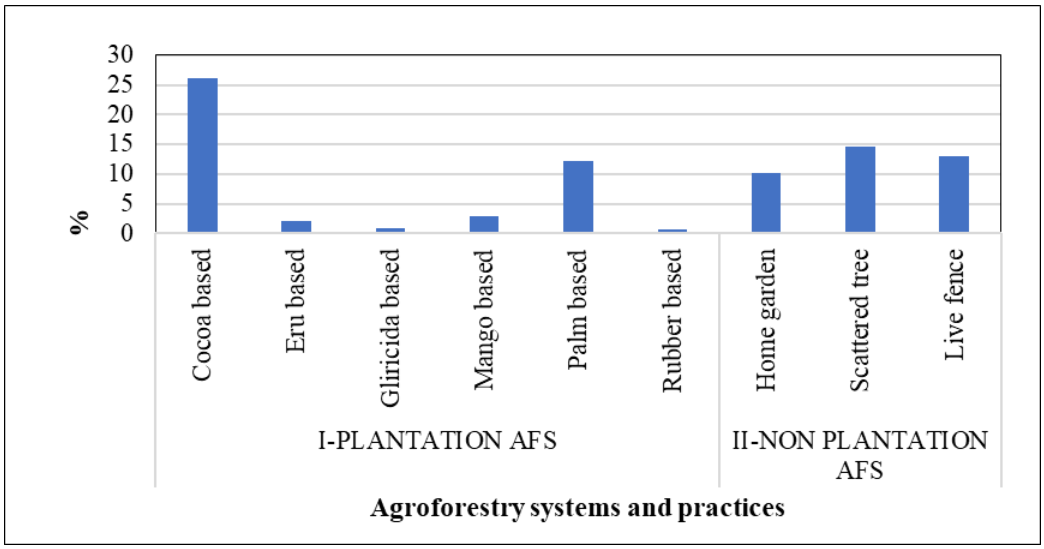

Figure 3 Distribution of agroforestry systems and prominent practices on farms of local communities of Tiko and Limbe III municipalies in South Western Cameroon

3.2. Home-gardens/homesteads cultivation

A homestead is viewed generally as an operational farm unit in which a number of crops including tree crops are grown with livestock, poultry and/or fish production, mainly for the purpose of meeting the routine basic needs of the farmer [21]; although home-gardens appear here to be a mixture of trees, shrubs and herbs, a certain general pattern seems to exist. There is wide variation in density of trees, species and crops based on the size of holding, needs of the people residing in homesteads and micro-climate. Banana, plantain, guava, mango, citrus, cashew and many multipurpose trees are the major trees found grown in home-gardens. Food crops include pineapple, okra, cocoyam, yam, groundnut, pumpkin, maize, potatoes, tomatoes, amaranthus, ginger and waterleaf. Domestic animals (goats, rabbits, pigs) and poultry are the main components of homesteads, even though less than half (43%) of the population keep them. The components are so intimately mixed in horizontal and vertical strata as well as in time that a complex interaction exists among soil, plants, other aboveground and below ground components, nutrition and environmental factors. There is critical competition both for light and nutrition. The holder chooses his crops and crop combinations based on his wisdom, needs and perceptions acquired over generations of experience.

3.2.1. Scattered trees on farm lands

The practice of growing agricultural crops under scattered trees on farm lands is old and does not seem to have changed for centuries. A plethora of trees were identified with varied densities. No specific arrangement could be described. The species diversity in these systems is high. Tree-crop combinations as described for the cocoa-based systems and home gardens were common. Trees are grown scattered in agricultural fields for many uses such as shade, fodder, fuel wood, fruit, vegetables and medicinal uses.

3.2.2. Trees on farm-boundaries/ Live-fence

Trees grown in agricultural fields are also often and usually grown on farm boundaries. Examples include bamboos, Cedrela, various multipurpose tree species, citruses, pear in association with food crops, spices and peace plant.

3.2.3. Fodder Banks

In this sylvopastoral system of agroforestry, various multipurpose trees (protein-rich trees) are planted on or around farmlands and rangelands for cut-and-carry fodder production to meet the feed requirements of livestock.

3.2.4. Non - agroforestry systems

Modern commercial plantation crops like rubber, cocoa, and oil palm represent a well-managed and profitable stable land-use activity in tropics. The scope for integrative practices involving plant associations in these commercial plantations is limited, except during the early phases of plantation when some intercropping is feasible, the commercial production of these crops is aimed at having a single commodity. However, on farmers' fields where planting densities of the principal crops are not respected as was the case in Tiko and Limbe III councils, most of the crops found in home gardens were found in the cocoa-, rubber- and mango-based farming systems.

Adoption of agroforestry system was linked with gender and age. Cocoa-based agroforestry practices were dominated by male-headed households (95%), while home gardens were dominated by female headed households (75%). The relationship between gender and choice of agroforestry practice was highly significant. Cocoa-based agroforestry was practiced mostly (65%) by 30 – 50 years old farmers, with differences in adoption between the age groups being highly significant. Home gardens were adopted predominantly (56%) by 18 – 30 years old farmers, with the differences in adoption between age groups being highly significant. Farmers aged between 18 and 50 years make up 87% of the sampled population. Palm-based agroforestry was practiced mostly (44%) by 30-50 years old farmers and scattered trees on farmland was mostly (73%) practiced by 18-30 years old farmers. The differences in the adoption of agroforestry practices between age groups were highly significant. With respect to gender and age group and for a more inclusive green economy, cocoa-based, home gardens, palm-based and scattered trees on farmland were identified as preferred agroforestry systems. Studies have shown that agroforestry practices such as multistrata forest gardens, mixed tree crop and home gardens, can reduce the vulnerability of the agricultural system to climate change, moderate water flows, store carbon and provide food, fodder and goods for cash [22,23]. Although farmers complained of the problem of shade provided by trees, shade is important for cocoa-based agroforestry practices. Cocoa is an understorey tree and research has shown that shade can increase the sustainability of the crop. How much shade is required still remains inconclusive in cocoa management. However, when properly established, shade for agroforestry systems acts as a buffering mechanism to temperature and storm events.

3.2.5. Some mensurational parameters (diameter, height and crown spread) of agroforestry practices

From Table 2, it is observed that maximum height was different in various practices, increases from mango-based, cocoa-based, palm-based, home garden, scattered tree, home garden, live fence and live fence+ animal, cedrela-based, rubber based, Cedrela-based and fodder bank. As for the tree density, the highest tree density (tree species richness) is found in cocoa-based, Eru in croplands + trees, rubber-in croplands, alley cropping, live fence and scattered trees, palm based, home garden, and mango on croplands, home garden, live fence and fodder bank respectively. The maximun crown diameter was aslo different in different practices especially obseved in cocoa-based, rubber –based, palm-based, scattered trees on farm land, home garden+ animal, mango-based, live fence + animal, eru in cropland) and live fence.

The fodder bank is characterized by most species occurring at low densities. Differences in tree densities in the agroforestry systems have resulted from the varying levels of disturbances experienced over the years from the conversion of the original coastal forest to farmlands. The destruction of plants and excessive opening of canopy gaps often stimulate growth of dense, herbaceous and semi-woody tangle that suppress tree regeneration. This condition is expected to prevail in the various systems for the foreseeable future because of tree harvesting to provide wood for firewood, construction fish smoking and other reasons. The mean tree density ranges from 4.0 trees ha $^{-1}$(Live fence)

to 211.5 tree ha—1(cocoa based) with standard deviation 114m tree ha—1. These values are lower than those observed by [24] in three Albanian virgin beech forests (320 to 388 stems ha1) and [25] in a nearnatural beech forest in Germany (263 stems ha-1) use of fodder bank as animal feed explain the reason why it has lowest density. This is no comfirmation with the authors who said that amongst the intended benefits, there are settlements, income generation, but more importantly agricultural expansion, fuelwood, and fodder [26 ,27]. Although the optimum densities would ensure sustainable supply of logs for fish smoking is now known to be the agroforest practices with low densities shows that the tree species have been over harvested.

Table 2 Some measuration parameters and statistics of trees (maximun, mean and minimum diameter, height and crown spread) on some agroforestry farms of local communities of Tiko and Limbe III municipalities in South Western Cameroon

Agroforestry practices		Diameter (cm)				height (m)				Tree density (trees/ha)				Crown diameter (cm)			
		min	max	mean	SD	min	max	mean	SD	min	max	mean	SD	Min	max	mean	SD
1	Rubber based	11.0	33.5	18.7b	0.29	5.0	16.0	9.7b	1.76	4	2520	523.4a	241.34	12.3	70	20.0a	0.01
2	*Cedrella*-based	8.0	43.0	27.2a	1.00	3.0	25.0	13.6b	0.00	4	2000	412.6a	2.23	12.0	54	19.1a	0.08
3	Coco-based	1.2	107.0	28.1a	1.15	1.0	67.0	12.4b	0.30	1	4444	211.5b	285.32	1.0	84	17.2a	0.10
4	Scattered tree	1.7	76.0	24.3a	0.92	1.8	38.0	11.5b	0.04	1	2000	53.8b	2.90	4.0	50.5	16.5a	0.07
5	Palm-based	5.0	79.4	25.2a	2.89	6.0	49.0	12.5b	1.36	5	1503	48.1b	357.13	1.0	60	14.3b	0.65
6	Fodder bank	2.0	30.2	14.3b	0.29	1.1	6.7	3.8b	0.03	3	21	15.0b	77.16	6.8	9.3	7.7b	0.29
7	Live fence + animal	7.0	100.0	20.5b	2.94	7.0	30.0	7.6b	0.01	1	2000	14.0b	12.21	0.6	36	14.3b	0.68
8	Mango-based	8.2	100.2	31.6a	2.43	6.5	69.0	14.7b	0.15	1	50	14.0b	18.03	4.0	44	9.0b	0.46
9	*Gliricida*-based	6.0	34.0	19.2b	0.83	5.2	11.4	20.0a	0.04	1	50	12.5b	40.67	3.7	34	10.0b	0.05
10	Home garden	0.5	106.0	19.2b	4.46	0.6	33.2	9.2b	0.06	1	64	10.2b	43.03	3.0	72.4	19.4a	1.52
11	Home garden + animal	2.0	90.5	19.2b	4.69	0.9	40.0	9.6b	0.01	1	42	7.9b	49.52	3.5	49.2	17.6a	1.73
12	Live fence	1.4	52.5	19.2	2.38	1.1	30.0	8.3b	0.03	1	24	4.0b	9.57	4.4	34	17.6a	0.44

The mean number of old and large living trees (dbh > 100 cm) in most agroforestry practices in the present study was 13 trees ha—1 This value is very close to those observed by [20] in three Albanian virgin beech forests (5–19 trees ha —1) and those reported for some of the most important beech-dominated, near-natural stands in France (12 23 trees ha—1); Denmark (8 14 trees ha —1) and Germany (13 trees ha—1). The occurrence of trees on farm as shown in this study is the result of natural regeneration as 90% of the respondents who indicated that trees on their farms were not planted and some farmers said that some trees are not compatible with their crops or plantations, like the cedrela plantation where most of the big trees were felt down. “Shade reduces photosynthesis, transpiration, metabolism and growth and therefore, the demand on soil nutrients and so enables a crop to be obtained on soils of lower fertility". Shade is invariably recommended for the establishment of cacao removed on optimal sites as the cacao becomes self-shading.

3.3. Stand structure in agroforestry systems

Stand structure as measured by the distribution of tree sizes in forest populations [20] shows non chacteristics distribution patterns owing to the disturbed nature of agroforestry systems of original coastal forest with clumbs and scatterd trees in farms delibrately retained by farmers for various objectives. Stand structure and specifically diameter distriburions of trees is an important variable which need to be considered in the development after harvesting the trees.

We observed that diameter size class ranging from 10 to 30 is the dorminant class. There were more individuals of the dorminant class in the rest of the systems. Probably because of timber harvesting activities and uncontrol logging. The uncontrolled logging usually destroys mature and young trees.

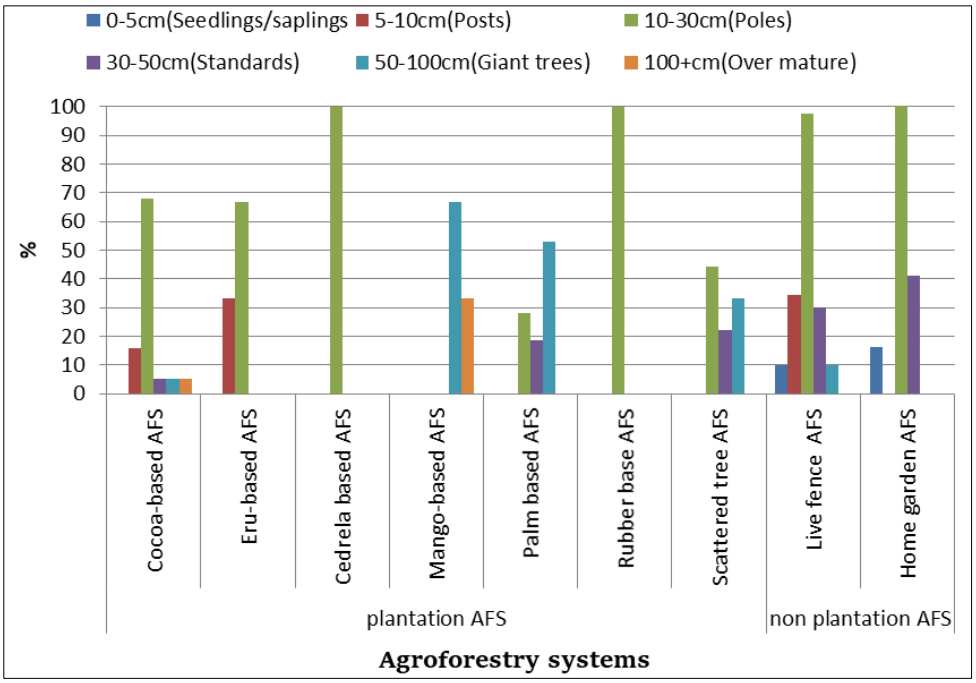

Figure 4 Relative distribution of tree sizes on farms of local communities of Tiko and Limbe III municipalities in South Western Cameroon

The former through extraction and the latter through destruction of regeneration. For practices with less than 50 trees ha-1 indicating that their population have been drastically reduced by the farmers. However a practice with herbs and regenerating trees like scattered trees on farmland, live fence, and home garden can recovered. At times there are no mature trees because of intensive harvesting, the poor natural regeneration in some agroforestry is because the seeds were depleted through harvesting of matured trees. Enrichment tree-planting could raise tree population. The number of trees in plantation agroforestry practices like cocoa-based and rubber- based are significantly different from those in other practices like scattered trees on cropland, Eru-based and home gardens. Certain practices had little or no relative diameter variation, like the Eru-based with just posts 5-10 and poles10-30cm. this may be due to the fact that Eru is a creeper and most farmer merged eru and Gliricidia in their farmlands and could not allow the tree to attain standards or giant trees to easy harvesting and avoid destruction. Home gardens with animals were also observed with poles and standards only because farmer could hardly plant trees for saplings/seedlings and they cut down giant trees for firewood and fish smoking. The highest number of over matured trees was observed in mango-based, this is because mango was the main plant producing food for commerce in these practices, and so was hardly fell down by farmers for firewood and construction wood. The diameter distributions of plantation crop stands showed the highest number of small recruits and a lack of full size canopy trees as a consequence of past cutting and current regeneration. The selective felling of large trees in these stands led to successful regeneration because of the creation of large gaps not readily covered by crown expansion of subdominant trees. At the Tiko markets, only logs with diameter < 40 cm were traded in form of heaps. A heap of 3 logs (equal to a cubic meter) with a length of 60 cm and a diameter comprised between 20-40 cm (0.0764m^3) cost 2.85€ or 37.33€/m^3 [28]This actually may be the reasons why standard diameter trees were not dominant in the distribution.

Appendix 1

Questionnaire for mangrove buffer agroforestry surveys

Sheet 1: Farm Questionnaire

Date……Zone : Core area [ ] Buffer zone [ ] Peripheral zone **[ ] Subdivision……**

village……Questionnaire N°……

Identification of farm owner

- Gender: Male [ ] Female [ ]
- Marital status: Married [ ] Single [ ]Widow/Widower [ ] Divorced [ ]Separated [ ]
- Age: less than 18 years [ ]18-30 years[ ]30-50 years[ ]50-70 years [ ] 70+ years [ ]
- Level of education: None [ ] Primary [ ] Secondary [ ] University [ ] other(s) Please specify……..
- What is the size of your household? ……..
- What is your principal activity? Agriculture [ ] fishing [ ] fishing smoking [ ]

  Animal rearing [ ] trader [ ] civil servant [ ] mixed farming [ ] others (please specify)……..

Information on "smart" Agroforestry practices

- What is the land tenure system of your land? Own [ ] Rent [ ] shared rights [ ] others (specify) ……
- Do you plant trees in your farmland? No [ ] yes [ ]
- List the crops that you plant in your farm and why?

Crop species	Reasons

If yes, list the tree species planted and provide reasons for the choice(s)

Tree species	Reasons

Use these options to guide your responses: Food for home [ ] firewood [ ] fish smoking [ ] Medication [ ] shade [ ] coppicing [ ] food for commerce [ ] soil fertility [ ] fodder [ ] others (please specify)…….

- How do you plant your trees in the farmland? Seeds [ ] graft [ ] cuttings [ ] vegetative multiplication [ ] others (please specify)…….
- If trees are not planted, are some trees selectively retained on the land during land preparation? Yes [ ] No [ ]
- Which functions do these trees perform? Use the guide in question 8 above.

Trees planted	Reason

- Do you use fertilizers on your farms? Yes [ ] No [ ]
- If yes, what type of fertilizers do you use in your farmland? Chemical fertilizers [ ] manure [ ] none [ ]
- State the quantity applied.
- If, No, how do you manage the fertility of your soil?
- Is the use of fertilizers increasing [ ] remain unchanged [ ] or decreasing [ ]?
- Do you use pesticides and other chemical inputs to control pests and diseases? Yes [ ], No [ ]
- State the quantity and amount used.

Kind of fertilizer	Farm size (Area)	Quantity (kg)

Pesticide	Quantity applied (kg)	Farm area (ha)

Is the use of pesticides and other chemical products for the control of pests and diseases increasing [ ] remain unchanged [ ] or decreasing [ ]?

- How will you rate crop yields on your farms? Very high [ ] High [ ] Average [ ] Low [ ] Very low [ ].
- Why do you rate it this way……..
- Is crop yield increasing [ ], remained unchanged [ ] or decreasing [ ] during the past five years?
- Do trees cause any problem with crops in your farm? Yes [ ] No [ ]. If yes, list them.
- ……
- How do you manage trees in your farmland? Pruning [ ] felling [ ] ordered planting [ ] rift [ ]

None [ ] others (please specify)……..

- Who manages these trees in your plots of land? Children [ ] men [ ] women [ ] all[ ]
- Do you rear animals? Yes [ ] No [ ]
- If yes how do you feed them?.....
- ……..
- Provide a list of animals you rear. ----------
- Do you plant mangrove trees in your land? Yes [ ] No [ ]

If no why?……

……

- Among the trees in your farm which tree do you prefer and Why? ……

……

……

- Is mangrove exploitation one of your income generating property? Yes [ ] No [ ]
- If yes how much (FCFA) per year?.....
- If yes what do you extract from the mangrove ecosystem……..
- ……..
- What are the production constraints in your farm?.....

……..

……..

- Have you ever heard of agroforestry? Yes [] No []
- Are you a member of any agricultural organization promoting agroforestry?

Yes [] No [ ] if yes which?.....

- Are you the land owner of your farmland?

Yes [ ] No [ ] if no who own the land: Private individual [ ] Council [ ] NGOs [ ] GIC [ ]

Chief [ ] SDO [ ] CDC [ ]If others (please specify)……

- The land that you farm is it enough for your agricultural practices? Yes [ ] No [ ] if
- No why.....
- List your sources of agricultural information. ……..
- Have you received any training on good agricultural practices in the past five years? Yes [ ] No [ ]

Perception survey

- Do you use mangrove (matanda)? Yes [ ] No [ ]

If yes for what?

i)Consumption uses :……..

ii) Non- Consumption uses :……

- How often do you use it? Daily [ ] weekly [ ] monthly [ ] others (specify)……
- How do you get it for use? Buying from local exploiters [ ]Self Exploitation [ ] others (specify)……..
- In the absence of mangroves, do you have any alternatives that can play the same role that mangroves play to you? Yes [ ] No [ ]
- How is support towards preserving the Cameroon Estuary mangroves ecosystem? Very high [ ] High [ ] Moderate [ ] Low [ ] Very low [ ]
- Since you started exploiting mangroves has any government personnel/agent attempted to stop you or tried to disturb you in any way? Yes [ ] No [ ]
- If yes, who? Divisional Officer [ ] Mayor [ ] MINFOF [ ] MINEPDED [ ] others (specify)……..
- Do people out of this community come here regularly to exploit mangroves?
- Yes [ ] No [ ]
- If yes, where do they usually come from? ……

2. Tree Inventory and mensuration of farm trees

Farm identification& characteristics

Date……Subdivision……Village……

Time : start ……Time: end……

Observer (s) ……..

Name of agroforestry system……

Type……..

GPS Fixes……..

Max length(m)……..Max width(m)……Farm age……..

N° of woody species…… Farm total tree density……Canopy closure :(close, dispersed)……..

Species inventory

Nº	Name of species		Habit				Age series (years)	Density (Number of individuals in the farm	Max height (m)	Max diam (cm)	Comments
	Local name	Sc, or common name	Creeping	Climber	Shrub	Tree					

Tree mensuration

Species			Age series years)	Nº of stems per tree	Diam class						Diam (cm)		Height (m)	Tree crown (m)		N0 of trees	Comments
No	Local name	Sc. Name/ common name			<5cm	5-10cm	10-300cm	30-50cm	50-100cm	100+cm	At 30cm	At 1.3m		D_1	D_2		

4. Conclusion and Recommendations

Farming system analysis geared towards contribution of buffer zone agroforestry to the sustainable management of mangroves and associated coastal forests within the South Western Cameroon observed that:

- Timber and fuel wood were the dominant use in the over 12 retained agroforestry practices.
- Adoption of agroforestry practices was linked with gender and age. Cocoa-based agroforestry practices were dominated by male-headed households, while home gardens were dominated by female headed households.
- Carbon stocks based on high mensurational parameters were obviously lower in the peripheral zone relative to the buffer zone for selected agroforestry practices except for cocoa-based practices. The first five preferred climate smart agroforestry types based on social, economic and ecological aspects were in the order: Palm-based > Cocoa-based > Rubber-based > Eru-based > Scattered trees on farmland.
- There was a high diversity of agroforestry practices and tree diversity with structural diversity reflecting forest disturbance mimicking the original coastal forest which has been converted into farmlands with a retention of farmlands which obviously limited the residual forest ability to supply basic ecosystem services, especially fuelwood/energy production, and carbon sequestration but playing a shielding role in front of the adjacent mangrove forest.

There is the need to expand the present study in other mangrove areas especially the mangroves of Cameroon Estuary which is the major deforestation hotspot in Cameroon

Compliance with ethical standards

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Disclosure of conflict of interest

The authors hereby declare no conflict of interest for this paper.

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