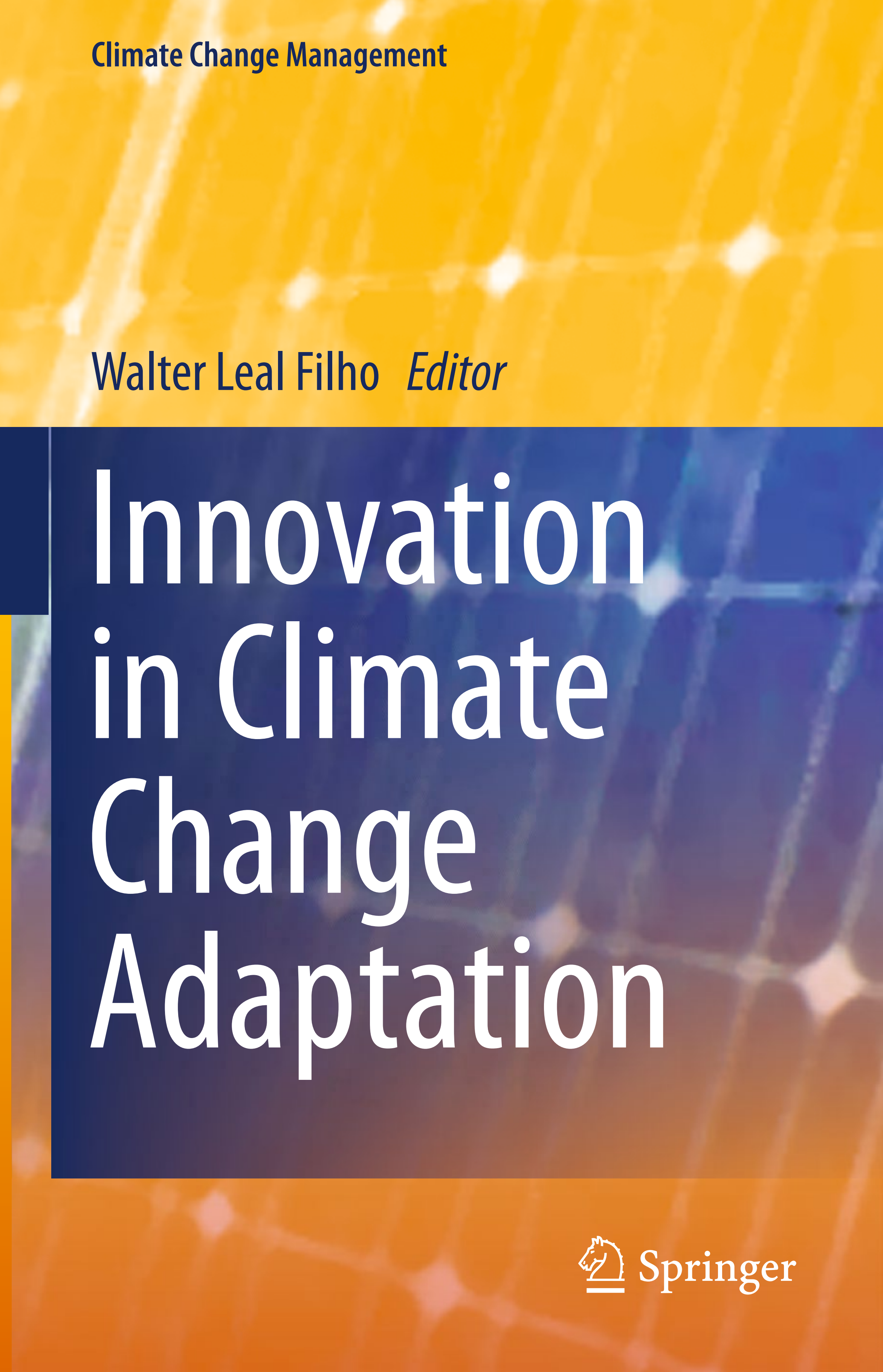

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Chapter 14
Comparative Analysis of Woody Composition of Farmlands and Forest Reserve Along Afram River in a Tropical Humid Savanna of Ghana: Implications to Climate Change Adaptation

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Abstract Riparian forests (RF) composition is important for moderating climate change impacts on agricultural watersheds. However, they are under threat from deforestation of catchment areas. The study used remote sensing techniques and field inventorying to assess woody species composition of RF on farmland (FA) and protected area (PA) along Afram rivercourse in the humid savanna of Ghana. Analysis of Landsat images revealed a reduction in forest cover from 1986 (50 %) to 2014 (31 %) in the river catchment. Ground survey of 60 randomly selected plots (500 m^2 per plot) equally divided between FA and PA along the river in a 50 m buffer zone showed a reduction in the number of woody species (diameter $\geq$5 cm) from PA (58) to FA (39). Shannon-Wiener Index for species diversity also reduced from PA (3.8 ± 0.05) to FA (3.1 ± 0.08). Diameter class distribution of species of both PA and FA showed a reversed J-shaped curve indicating successful regeneration. Reduction in species density per hectare from PA (545 ± 18) to FA (277 ± 13) is likely to increase the surface exposure of the riparian area in FA. This will heighten risks of climate disasters such as fires and flooding. Education of farmers on the importance of riparian forests may ensure their protection.

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Introduction

In the savanna agricultural landscape, riparian forests are naturally resilient to climate change impacts as the continuous supplies of moisture coupled with the topographic heterogeneity and closed linear canopy limit grassy fuel loads, increase relative humidity, decrease temperature and wind speed to reduce fire risks (Sambare et al. 2011; Azihou et al. 2013). Ecologically, riparian forests (RF) are important as they protect farmlands from flooding, drying and sedimentation (Sambare et al. 2011; Gray et al. 2014). They also serve as habitat for fauna such as birds, insects and other organisms that are essential for crop pollination, seed dispersal and nutrient cycling (McCracken et al. 2012; Gray et al. 2014). Riparian forests have social benefits including provision of tourism, medicines, nutrition, firewood, and raw material for different crafts and construction (Ceperley et al. 2010; Gray et al. 2014). Culturally, riparian forests are sometimes designated as sacred groove (Ceperley et al. 2010). Due to these functions and many others, RF are protected by international conventions, national laws and policies (McCracken et al. 2012; Gray et al. 2014).

Within the water-limiting savanna environment, riparian catchments are hotspots for agricultural production (Natta et al. 2003; Goetze et al. 2006). As a result, riparian forests are under threat of deforestation which consequently changes their microclimatic conditions to increase climate change effects on species and associated functions (Callo-Concha et al. 2012). Globally, land areas dedicated to agricultural production are much greater than protected forest reserve areas (Traoré et al. 2012; Gray et al. 2014). This means that agricultural landscapes cannot be excluded from biodiversity conservation (Gray et al. 2014). With appropriate management, agricultural landscapes can contribute to the preservation of biodiversity and delivery of ecosystem services (McCracken et al. 2012; Gray et al. 2014). However, in spite of the global knowledge on the threat of agricultural production to riparian forests, our understanding in this area is limited in the tropical savannas of Ghana and West Africa in general (Natta et al. 2003; Ceperley et al. 2010; Sambare et al. 2011).

Several studies have demonstrated that farming activities cause deforestation and reduce the woody composition (diversity and structure) on agricultural landscapes (Ceperley et al. 2010; Okiror et al. 2012). In other studies, farmlands maintained high woody composition suggesting that not all farming practices have negative effects on biodiversity (Boakye et al. 2012; Traoré et al. 2012; Gray et al. 2014). To enhance the management of riparian forests in savanna agricultural landscape, this study compares woody vegetation composition in farmlands and that in protected forest reserve area by using the headwaters of the Afram river located in the humid savanna of Ghana as the case study. Two related hypothesis are tested in this study. Firstly, riparian forest in protected area hosts a higher diversity of woody species than on farmland (Ceperley et al. 2010; Okiror et al. 2012). Alternatively, no such diversity is observed in protected area (Boakye et al. 2012; Traoré et al. 2012). Secondly, the structure of the riparian woody species on farmland mimics that in protected area (Traoré et al. 2012). Alternatively, the riparian forest structure on farmland differs from the protected area (Boakye et al. 2012). The paper concludes on the findings of the research in the light of climate change adaptation on farmlands in the savanna zones of Ghana. It is anticipated that this will serve as an important baseline for the management of farmland biodiversity as well as the enforcement of the freshwater buffer zone policy of Ghana.

Materials and Methods

Study Area

The study was conducted in the headwaters of the Afram river catchment in the north-eastern part of the Ashanti region of Ghana (Kyerematen et al. 2014) (Fig. 14.1). The climate of the river catchment is characterized by distinct wet and dry seasons. The highest rainfall occurs between May and October and the annual average is 1400 mm. The hottest months occur from January to April and the annual average is 27 °C. The soil is composed of a well-drained sandy loam (Callo-Concha et al. 2012). The topography is flat to gently undulating with small areas of steep slopes occurring locally. The vegetation consists of Guinea savanna which forms a transition zone between closed forest and the Sudan savanna. Along the Afram river is located the Kogyae Strict Nature Reserve [Protected Forest Reserve

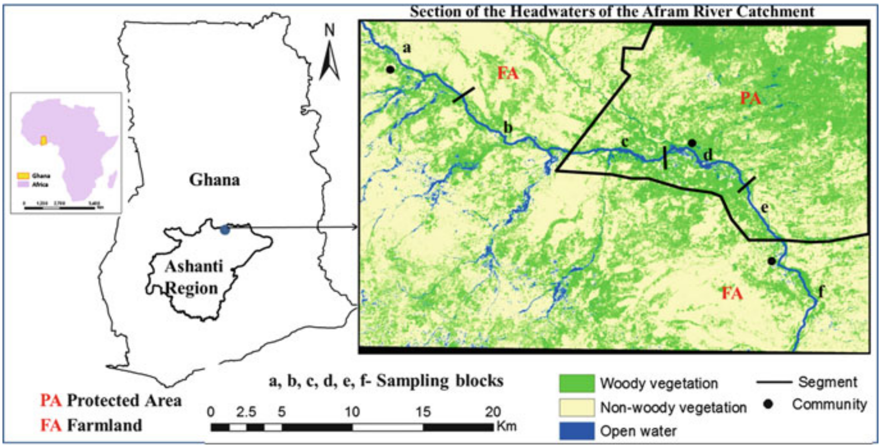

Fig. 14.1 The location map of a section of the research area in Ghana

Area (PA)], gazetted in 1971. Protected area (PA) is defined as clearly delimited area of natural vegetation that have been officially classified with appropriate legal status by public authorities with the aim of ensuring protection of natural resources as well as ecosystem functions and services (Traoré et al. 2012). The Kogyae reserve was thus established to protect the tributaries of the Afram river and also as refugeum for wildlife within the locality. The Kogyae reserve is under the management of the Forestry Commission of Ghana. The main land use activity of the communities in the vicinity of the reserve is farming (FA) and along the river, cereals are the widely cultivated food crops. The farmlands are affected by various anthropogenic activities including extensive livestock grazing, bush fires, and various harvestings of timber and non-timber forest products such as wood, leaves, bark, flowers and fruits (Kyerematen et al. 2014; Egyir et al. 2015).

Forest Cover Assessment (1986–2014)

Selection of Landsat Images and Ground Control Points

Satellite data inputs for multi-temporal studies of forest cover were obtained from the Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+), and Landsat Operational Land Imager (OLI). The images (Table 14.1) were downloaded from the United States Geological Survey National Center for Earth Resources Observation and Science via the GLOVIS data portal (http://glovis.usgs.gov/). Images with no cloud cover and which were available within the time frame in 1986, 2000 and 2014 were downloaded. All the dates of the selected images were within the dry season when the grassy layers have been scorched thereby increasing the detectability of forests. The Landsat images were geo-referenced to UTM projection WGS 84.

During the fieldwork from September to December, 2013, ground control points and forest canopy density data were collected using GPS and spherical densiometer respectively to classify the 2014 Landsat image. Ground control points for the classification of the 2000 Landsat image was collected with reference to a historic Landcover map prepared for the study area under the GLOWA-Volta Project (Volta Basin Authority Geoportal 2000). This was done by first identifying the features on the Landcover map prepared in 2000 and which could still be verified during fieldwork. This entailed identifying stable landcover in the protected area, along the Afram river, farms and settlements, which had been in existence since 2000.

Table 14.1 Attributes of the Landsat TM, ETM+ and OLI imagery used in the study

Acquisition date	Sensor	Spatial resolution (m)	Path/row
9/02/1986	TM	30	194/55
14/03/2000	ETM+	30	194/55
8/01/2014	OLI	30	194/55

Forest Classification (1986–2014)

Supervised classification procedures using ERDAS Imagine 2011 software were implemented to classify the Landsat images using the Maximum Likelihood Classification algorithm. Areas with tree canopy of 20 % and greater were located on the image and signature were selected and used as training set for classifying "forest areas". Areas with less than 20 % of canopy were classified as "non-forests". This procedure was undertaken with reference to Potapov et al. (2009). In the case of the 1986 map, reference was made to the original topographic map of the catchment published in the management plan of the Kogyae Nature Reserve (Wildlife Department of Ghana 1994) plus local knowledge from the field. Further, qualitative assessments of the classified images were done by examining the classified images visually and relating it to field knowledge. This ensured that the classified map output reflected reality. Protected forest reserve area boundary was obtained from the geodatabase of the Forestry Commission of Ghana. Analysis of forest cover in terms of area for 1986, 2000 and 2014 were carried out in ArcGIS 10.1.

Accuracy Assessment of Forest Classification

Fifty percent of the collected ground control points (test data set) were used for the accuracy assessment of the Landsat map of 2000 and 2014. The classified images were then crossed with the test data to generate confusion matrix. The confusion matrix was used to calculate the different accuracy measures i.e., producer's, user's accuracy, class mapping accuracy for each class and the overall accuracy. Kappa statistics were also calculated as additional information for evaluating the accuracies of the maps. It was not possible to carry out accuracy assessment for the 1986 map because of the lack of a satellite derived historical reference map. It is however, assumed that the accuracy assessments for the Landcover maps of 2000 and 2014 are sufficient to shed light on the overall classification procedures adopted for this study.

Woody Vegetation Inventory

Sampling

Owing to the narrow extent of riparian forest in a landscape, high resolution image, ALOS AVNIR (10 m) of 27 February, 2011 (Fig. 14.1) was utilized for mapping woody vegetation within the river catchment with maximum likelihood classification algorithm (Bagan et al. 2012) at accuracy of 89 % (Fig. 14.1) (confusion matrix not shown) to facilitate inventory with stratified randomized design in Farmland (FA) and protected area (PA). Whether in PA or FA, the rivercourse was divided into three segments, each of length, ranging 6–8 km at a buffer zone of 50 m on each side of the river channel. The inventory for species with diameter at breast height (DBH) ≥ 5 cm was conducted in 60 random rectangular plots (500 m^2 per plot), 30 each in PA and FA and 10 plots per segment. Tree caliper was used to measure the DBH of the species and the height was measured with Vertex IV and Transponder III, Haglof Sweden. Specimens of the species recorded were taken to the herbarium of the Forestry Research Institute of Ghana for confirmation of identification.

Analysis of Woody Species Richness and Diversity

Shannon-Wiener (SWI) (Shannon 1948) and Simpson (SI) (Simpson 1949) indices were calculated as measures of woody species diversity. Further Pielou Equitability index (Natta et al. 2003) was used to assess the evenness of the species distribution.

$$\text{Shannon-Wienerindex (SWI)} = -\sum P_i \ln P_i$$

where $P_i = n_i/N$ with $n_i =$ number of individuals of species i and $N =$ total number of individuals in a plot.

$$\text{Simpson index (SI)} = 1 - \sum {P_i}^2$$

$$\text{Pielou Equitability index (PEI)} = \text{SWI}/Hm$$

where $Hm = \ln S$ with $S =$ number of species in a plot.

These indices are commonly used for forest and savanna diversity assessment in Ghana and West Africa in general (Boakye et al. 2012; Traoré et al. 2012; Tom-Dery et al. 2013). They were adopted in the study to facilitate comparison of the findings. Species richness (SR) used in this study refers to the number of different species recorded in a plot.

Structure and Size-Class Distribution of Species

For each landuse management regime (PA or FA), the following structural parameters were calculated:

1. Woody species density; the average of the number of individuals per hectare
2. Basal area; the average cross-sectional area of woody species per hectare was calculated from the DBH below:

$$\text{Basal area} = \sum \left(\text{DBH}^2 \pi 4^{-1}\right) \text{ where } \pi = 3.14$$

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To establish the size-class distributions, diameters of all species were used to construct histogram with size classes of 5 cm interval. This was similarly done for the heights of species at 5 m interval classes.

Student's *t*-test was used to estimate the significance of the differences between the protected area and farmland after testing for normality using Statistical Package Software for the Social Sciences, Version 17. Results were considered significant at $P < 0.05$.

Results

Landcover Maps and Accuracy Assessment

The quantified forest cover trends mapped between 1986 and 2014 are depicted in Table 14.2 and Fig. 14.2. The trend generally shows increasing deforestation from 1986 to 2014. In 1986, the forest cover was estimated at 50 % of the entire

Table 14.2 Landcover proportions from 1986 to 2014 at the Afram catchment

Landcover	1986	%	2000	%	2014	%
Forest (ha)	143,453	50	105,595	37	87,897	31
Non-forest (ha)	142,497	50	180,355	63	198,053	69
Total	285,950		285,950		285,950	

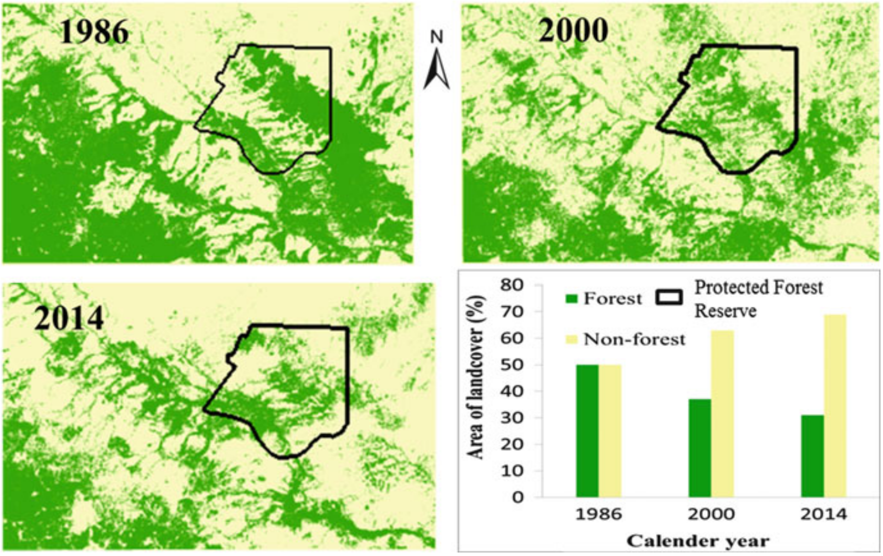

Fig. 14.2 Landcover in the headwaters of Afram river catchment for the studied years (1986–2014)

headwaters studied and was reduced to 37 % by 2000. Currently, the area of forest cover is only 31 % of the headwaters of the Afram river catchment. The "non-forest" which comprises primarily farmland and grassland have been increasing in area coverage since 1986 (50 %) through 2000 (63 %) to 2014 (69 %).

Within the protected area only (PA) (Table 14.3), the quantity of forest has been reducing steadily from 1986 (54 %) through 2000 (42 %) to 2014 (40 %). Analysis of forest cover on farmland (FA, outside the protected area) also shows decreasing forest area from 1986 (50 %) through 2000 (36 %) to 2014 (30 %) (Table 14.3).

The results of the classification accuracy assessment for 2000 and 2014 maps are presented in Tables 14.4 and 14.5 respectively. Overall accuracies of 89 % for the 2000 image and 91 % for the 2014 image. The Kappa coefficient for 2000 and 2014 were 0.77 and 0.83 respectively. The "forest" and "non-forest" classes of both 2000 and 2014 had producer's and user's accuracies over 80 %.

Table 14.3 Forest cover conversions from 1986 to 2014

Landuse	1986	%	2000	%	2014	%
Protected area (ha)	18,137	54	14,128	42	13,437	40
Farmland (ha)	125,316	50	91,468	36	74,461	30

Total area of protected forest reserve = 33,587 ha, Total area of farmland = 250,632 ha

Table 14.4 Confusion matrix of Landcover map using Landsat 2000

	Reference data		Accuracy total				
	Forest	Non-forests	Classified total	Number correct	Producers accuracy (%)	User accuracy (%)	Kappa
Forest	29	2	31	29	80.56	93.55	0.88
Non-forest	7	42	49	42	95.45	85.71	0.68
Total	36	44	80				

Overall accuracy = 89 %
Overall Kappa = 0.77

Table 14.5 Confusion matrix of Landcover map using Landsat 2014

	Reference data		Accuracy total				
	Forest	Non-forests	Classified total	Number correct	Producers accuracy (%)	User accuracy (%)	Kappa
Forest	36	1	37	36	85.71	97.3	0.94
Non-forest	6	37	43	37	97.37	86.05	0.73
Total	42	38	80	73			

Overall accuracy = 91 %
Overall Kappa = 0.83

Woody Species Richness and Diversity

A total of 63 woody species distributed within 24 families were recorded along the Afram river in both PA and FA. Three most species rich families in both protected area (PA) and farmland (FA) were Fabaceae (36 %), Rubiaceae (13 %) and Moraceae (8 %). The total number of specimen recorded was 1232 with 817 in PA and 415 in FA. The number of species decreased from PA (58) to FA (39). With this, 34 species were common to both PA and FA. Twenty-four and five species were found exclusively in PA and FA respectively. Examples of the species found only in the PA were *Albizia glaberrima* (2 %), *Albizia zygia* (1 %), *Alchornea cordifolia* (1 %) etc. The five species recorded exclusively in FA were *Acacia macrostachya* (1 %), *Anthocleista nobilis* (1 %), *Azadirachta indica* (1 %), *Canthium vulgare* (2 %) and *Raphia hookeri* (1 %). Some of the species common to the PA and FA were *Pterocarpus santalinoides* (11 %), *Mitragyna inermis* (11 %), *Cynometra megalophylla* (7 %) etc.

Furthermore, six dominant species in the PA were *Pterocarpus santalinoides* (12 %), *Mitragyna inermis* (11 %), *Cynometra megalophylla* (7 %), *Antiaris toxicaria* (6 %), *Ceiba pentandra* (5 %) and *Sterculia tragacantha* (4 %). Similarly, 6 dominant species on FA were *Mitragyna inermis* (12 %), *Cynometra megalophylla* (9 %), *Pterocarpus santalinoides* (8 %), *Antiaris toxicaria* (6 %), *Diospyros mespiliformis* (5 %) and *Anogeissus leiocarpa* (4 %). The diversity of the riparian species on FA was significantly lower than that in the PA in any of its measures (SWI, SI, PEI, SR) (Table 14.6).

Structure and Size-Class Distribution of Species

There was a significant reduction ($t = 12.4$, $df = 58$, $p < 0.0001$) in the mean density of woody species from the protected area (PA) (545 ± 18) to Farmland

Table 14.6 Diversity of woody species on farmland ($n = 30$) and protected aea ($n = 30$)

Diversity	Landuse	Mean	SE	t-value	p-value
SWI	PA	3.80	0.05	7.84	<0.0001*
	FA	3.10	0.08		
SI	PA	0.95	0.003	3.02	0.004*
	FA	0.93	0.007		
SR	PA	15.3	0.49	8.56	<0.0001*
	FA	9.7	0.44		
PEI	PA	0.96	0.003	2.19	0.032*
	FA	0.94	0.01		

SR, SWI, SI and PEI connote Species Richness, Shannon-Wiener, Simpson, and Pielou Equitability Indices respectively. *SE* Standard Error, Degrees of freedom (58)
*$p < 0.05$

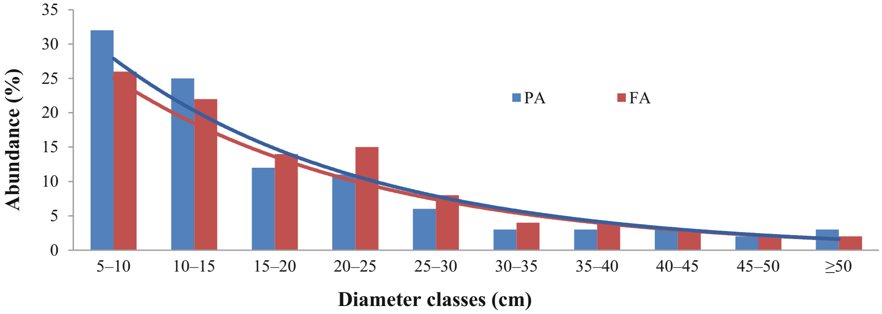

Fig. 14.3 Diameter class distribution of individuals' ≥5 cm DBH in riparian forests in protected area (PA) and farmland (FA)

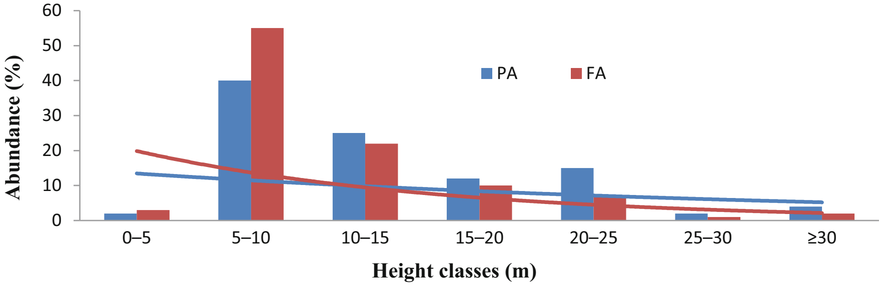

Fig. 14.4 Height class distribution of individuals' ≥5 cm DBH in riparian forests in protected area (PA) and farmland (FA)

(FA) (277 ± 13). The mean basal area of woody species per hectare also showed a significant reduction ($t = 2.603$, $df = 58$, $p = 0.01$) from the PA (19.63 ± 1.74) to FA (14.10 ± 1.22). The diameter class distribution of woody species of RF on FA was similar to that in PA as both showed a reversed J-shaped curve with high number of individuals of diameter less than 15 cm (Fig. 14.3). The height classes' distribution of the species also followed a similar trend as the diameter classes (Fig. 14.4). A high number of individuals had heights between 5 and 10 m for both PA and FA.

Discussion

Landcover Map Accuracies

The confusion matrix of the 2014 classification was an improvement over the 2000 classification product (Tables 14.4 and 14.5). This could be as a result of the use of current validation dataset as observed during fieldwork as opposed to the 2000 classification where reference was made to historic Landcover map and local knowledge. For both 2000 and 2014 classifications, errors were minimized by choosing only two landcover classes (forest/non-forest), with spectrally distinct signatures. The accuracy of the 2000 and 2014 classifications exceed the 85 % overall accuracy threshold used by the United States Geological Survey to determine acceptability (Chai et al. 2009).

Forest Cover Change

Forest cover change assessment is an important starting point for understanding degradation patterns in any ecosystem. The result of the landcover change analysis (section "Landcover Maps and Accuracy Assessment") shows the deforestation of the headwaters of the Afram river in both protected area and on farmlands between 1986 and 2014 (Fig. 14.2 and Table 14.3). This is an indication that the protected area has not been completely successful in preventing habitat destruction within its boundary. The finding is not peculiar to the study area. This is because evidence of deforestation has been reported in protected areas across the tropics (Chai et al. 2009; Traoré et al. 2012). Consequently, concerns have been raised on the effectiveness of protected area management for biodiversity conservation (Chai et al. 2009; Traoré et al. 2012). The effects of deforestation includes changes in elements such as light and wind which influence the microclimatic conditions of the forest remnants to exert a strong effect on biological diversity (Goetze et al. 2006). However, within the tropical environment, deforestation is as a result of humans striving to meet basic needs of food, energy and shelter. Farmers remove woody vegetation and in turn replace them with crops (Kyerematen et al. 2014; Egyir et al. 2015). Also rural households depend on fuelwood as their main source of energy, and the increasing demand by the populace contribute to the reduction in forest area (Kyerematen et al. 2014). Again due to illegal activities of hunters and poachers, wildfire is prevalent within the protected area and farmlands of the study area, which according to Callo-Concha et al. (2012) contributes to tremendous forest loss annually.

Changes in Riparian Woody Species Richness and Diversity

Although not all forest cover conversions have negative effects on biodiversity (Traoré et al. 2012), field inventory in this study have confirmed a reduction in the number of woody species in riparian forests (RF) on the farmland (FA) when compared to that in the protected area (PA). This finding in the FA was unexpected as riparian forest is designated as protected area in all landscapes under the freshwater buffer zone policy of Ghana (Government of Ghana 2011). Controlled human activities in protected areas play important role in reducing disturbance on biodiversity than lands outside protected areas (Okiror et al. 2012). Therefore, the reducing species on farmland could be as a result of the poor enforcement of the policy prescription prohibiting agricultural activities in the buffer zone (Government of Ghana 2011).

The result (Table 14.6) further showed that the riparian forest in PA is significantly diverse as oppose to the FA. This is also reported in other studies (Ceperley et al. 2010; Okiror et al. 2012) and on that basis, the first null hypothesis is accepted. In contrast to this research, it has been found in other studies that the species diversity value on agricultural watershed in the tropics is enhanced as a result of deliberate preservation of trees by farmers (Boakye et al. 2012; Traoré et al. 2012; Gray et al. 2014). In spite of the reducing farmland diversity in this study, the Shannon-Wiener diversity values of both FA and PA are within the range (2.4–5.4) reported in other savannas of West Africa (Natta and Porembski 2003; Natta et al. 2003) indicating that the RF in the study area (PA and FA) still has the potential to conserve high species diversity (Okiror et al. 2012). This could be as a result of the intensity and frequency of floods, small-scale variation in topography, soils and canopy structure of the riparian area that create a diversity of habitats for a wide variety of species to co-exist (Sambare et al. 2011).

The fact that the RF on farmland is less diverse reduces its resilience to disturbance (Scherer-Lorenzen et al. 2005). Studies have shown that less diverse ecosystems are prone to climatically induced catastrophes such as diseases and alien species invasions (Scherer-Lorenzen et al. 2005). Under this situation, the ability of the forests to provide ecosystem services and functions needed for sustainable food production is hampered (Eilu et al. 2003; Manning et al. 2006; Okiror et al. 2012). Loss of floral diversity results in poor habitats conditions which are detrimental to the survival of climate sensitive faunal species such as birds and insects that are essential for crop pollination, seed dispersal and nutrient fixation on farmlands (Sambare et al. 2011).

Structure and Size-Class Distribution of Species

The “J” shaped curve distribution (Figs. 14.3 and 14.4) of diameters of riparian woody species on farmland (FA) mimic that in the protected area (PA) as stated in the second null hypothesis. This means that the woody species on FA has the potential to regenerate naturally and face no danger of extinction (Sambare et al. 2011). According to Lykke (1998), for a population to maintain itself, it needs to have abundant juveniles which will recruit into adult size classes. This type of species distribution gives the ecosystem a stable population structure for the sustenance of the ecological succession of riparian forests (Sambare et al. 2011). Under this condition, the forest cover is perpetually maintained to regulate periodic events such as floods and drought that have damaging effects on crop production and greatly increases concerns over food supply (Okiror et al. 2012).

The decline in the density and basal area of the woody species (section "Structure and Size-Class Distribution of Species") on FA, may have been caused partly by the repeated manual weeding of the riparian area for crop cultivation (Ceperley et al. 2010). Also the use of agro-chemicals for weeding may have affected the regenerative capacity since some of these chemicals kill the seeds that are dispersed (Fischer et al. 2009; Ceperley et al. 2010). The fact that the riparian woody density is lower in FA is likely to result in a much drier forests due to the increase in the surface exposure of the riparian area for soil moisture loss. This increases the vulnerability and frequency of the riparian forests to wildfires (Sambare et al. 2011; Azihou et al. 2013). Such fires can break the resilience of the riparian ecosystem to intensify climate change impacts to such a degree that species physiological tolerances can be exceeded and the rates of biophysical forest processes altered (Scherer-Lorenzen et al. 2005).

Conclusion and Recommendation

Riparian forests in the headwaters of the Afram river in the humid savanna of Ghana contribute to the conservation of high woody species composition. That notwithstanding, reduction of forests cover from 1986 to 2014 coupled with the decline in the woody species composition in the riparian forests from protected area to farmland may be increasing the risk of the riparian area in the farmlands to climate change impacts such as fires and flooding. On that basis, the first null hypothesis of this study is accepted due to the high riparian diversity value in the protected area as oppose to that on the farmland. The research finding also supports the second null hypothesis partly in that the diameter distribution of the riparian woody species on farmland mimics that in the protected area. The basal area and density were lower for the riparian woody species on farmland. To ensure the continuous flow of benefits from the riparian forests for sustainable food production and farmlands' resilience to climate change, it is important that riparian biodiversity is sustainably managed. This may be achieved by enforcing the freshwater buffer zone policy of Ghana. There should also be the conscious effort to educate farmers to retain riparian woody species or replanted to enhance the composition. The study further recommends that the buffer zone is excluded from farming for the full recovery of the riparian forests.

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