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Full Length Research Paper

Land cover changes and their determinants in the coral rag ecosystem of the South District of Unguja, Zanzibar

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This paper presents the findings on the study on land cover changes and their determinants in the coral rag ecosystem of the South District of Unguja. The study is based on data extracted from the 1975, 2009, and 2014 satellite images using remote sensing and geographical information systems (GIS) techniques. Additional data were collected through structured interviews in a household survey, focus group discussions, key informant interviews, transect walks and observation. The major change detected in the study area from 1975 to 2014 was the decline of forests by 28.3% from 43.31 to 15% and the increase of semi-open forest and bush by 24.16% from 10.54 to 34.7%. During the same time, settlements increased from 0.1 to 4.9%. Different factors both direct and underlying have caused land cover change in the study area. Direct causes include shifting cultivation, commercial cutting of wood for fire wood, charcoal, pegs and cutting sticks for seaweed farming, while the underlying ones are population growth, policy reform and policy failure, land tenure insecurity, soil as well as the terrain and underlying rocks. If not properly addressed, land cover changes are likely to affect either positively or negatively the wildlife as well as the livelihoods of the communities. Investment in intensive cultivation and alternative sources of energy is required to reduce over utilization of forest resources and to improve conservation and people's livelihood.

Key words: Land cover change, coral rag ecosystem, fragmentation, forest decline, Unguja Island.

INTRODUCTION

In recent decades, land cover change has been considered as one of the major global environmental problems (Fuchs et al., 2018; Nyamugama and Kakembo, 2015; Schoeman et al., 2013; Ouedraogo et al., 2010). It has become an area of interest to many researchers and scientists including bio-geographers, ecologists and natural resource managers to gain deeper understanding of its causes and consequences to the planet earth. FAO (2016, 2010a) maintains that about half of the world forests have already been cleared and every year the planet earth loses about 16 million hectares of her forests. Accordingly, more than 60% of the annual forest losses worldwide have occurred in the tropics, particularly in Latin America and in Africa. The tropical forests in Ivory Coast, Congo, Gabon, Sierra Leone, Madagascar and the tropical forests in Southern

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and Eastern Africa have been greatly reduced from degradation and deforestation (Chakravarty et al., 2012). Besides, the rate of deforestation in Tanzania is approximately 1.13% per year; approximately, 403,000 ha of forest were being annually lost mostly on village land (FAO, 2010b; Sawe et al., 2014).

Land cover change is complex, involving various interacting factors which vary in space and time (Dalil and Nsini 2014; Misana et al., 2012). On one hand, the variation of factors reflects the dynamic nature of peoples' behavior in the way they interact with their environments, that is, the way they feel, view and respond to their environment in space and time (Orjala, 2008). The way human beings interact with their environment is a response from certain stimuli that are rooted in socio-economic and political decisions at different levels and in different times. On the other hand, the variation of factors reflects the dynamic nature of the physical factors such as soil, climate and morphology (Gao et al., 2015).

Although land cover changes had occurred in the past, they were mostly a result of natural processes and had little effects on the biosphere (Fanan et al., 2011). Recently, the problem has become complex, fast growing, and mostly caused by human activities (Baral et al., 2018; Bayramoğlu and Kadıoğulları, 2018; Mwangi et al., 2017a; Alemayehu, 2016; Dalil and Nsini, 2014; Mdemu et al., 2012; Misana et al., 2012). The major concern on land cover change has emerged following the massive removal of the natural vegetation by human activities (Kull, 2012; Misana et al., 2012). The intensity of changes has been propelled by direct and indirect causes arising from human decisions at global to local levels (Solomon et al., 2018; Mwangi et al., 2017b; Adedeji et al., 2015). The decisions determine the human actions to control and access natural resources, leading to clearing of natural vegetation. The massive removal of natural vegetation in the biosphere has contributed to the imbalance of the radiation budget causing global climate changes, biodiversity loss and threats to human wellbeing (Zaehringer et al., 2015; Misana et al., 2012; Fanan et al., 2011).

Although, Islands are often known to have high percentages of endemic species (Groom et al., 2006), most of the Island environments are subjected to land transformation due to deforestation from cultivation, sand mining/quarrying as well as urban and sub-urban expansion (Devaraju et al., 2015; Azeria et al., 2006; Fahrig, 2003). Island environments are fragile, thus uncontrolled utilization of land and forest resources has great repercussion on both land cover and biodiversity conservation (Calado et al., 2014). Similarly, the size of land is limited (small), while human population is growing fast (Ewel et al., 2013). Thus, there has been increasing pressure on forest resources from utilization and demand for land. Consequently, habitat fragmentation and loss of biodiversity are increasing in many islands (Calado et al., 2014; Ewel et al., 2013; Baider et al., 2010).

The problem of land cover change in Unguja Island is not different from other Islands. Most of her natural vegetation has been removed since colonial period (Siex, 2011). The coral rag vegetation of the South District of the Island, however, has remained as the largest natural vegetation cover, constituting about 63% of the Island vegetation (*ibid*). Accordingly, the ecosystem predominantly consists of indigenous coral rag forests and scrubland, which are recognized as the only remaining important wild habitat in the Island. The natural vegetation is known as 'coral rag vegetation' as the ecosystem constitutes a rubbly limestone of ancient coral reef material (Hettige, 1990). In recent years, however, the natural coral vegetation has been changing due to the increasing human development activities as well as increasing utilization of forest resources (Kukkonen, 2013).

Recognising the importance of the coral rag ecosystem to wildlife and human well being, it has become necessary to undertake a study to understand the nature and extent of land cover changes as well as assess the driving forces behind them. This paper presents findings of the study that was undertaken in the South District of Unguja Island to analyze land cover changes and their drivers. The information generated in this study is vital for conservation of wildlife and forest as well as for sustainable human development.

MATERIALS AND METHODS

The study area

The study was conducted in the South District of Unguja Island. The Island lies off the coast of East Africa in the Indian Ocean slightly south from the Equator (5° - 6° 30′ South and 39°23′ - 39°34′ East) and just 40 km east from Tanzanian mainland (Figure 1). The Island is 85 km long (North to South) and an average of 39 km wide (East to West), with an area of 1660 km^2. Specifically, the study area is located at latitudes 6° 10′ 30′′ South - 6° 29′ 30′′ South and longitudes 39° 23′ 30′′ East - 39° 34′ 30′′ East with an area of 379.3 km^2. Out of 21 Shehias of the study area, 6 Shehias, which are equal to 30%, were selected for the study. The selected Shehias were Mtende, Kizimkazi Mkunguni, Pete, Paje, Jambiani Kibigija and Muyuni 'A'. The Shehias are traversed by the coral rag ecological region.

The climate of the South District of Unguja is described in detail in Klein and Kayhko (2008). Generally, the district receives tropical rains during the short and long rain seasons. Accordingly, the average rainfall is 1100 mm; this amount is below the average for the Island, which is 1600 mm. The average annual daily maximum temperature is 29.3°C and the minimum is 21.1°C. The temperatures are the highest in January and February, with a mean maximum temperature of 32°C.

The district is almost dominated by Quaternary coral rocks. It is characterized by the much younger (Quaternary <2.5 millions years) deposits, that form a succession of cliffs (Klein and Kayhko, 2008). The soil of the study area is shallow and lies above a bed of reefels lime stones. Such soil supports shifting cultivation. The natural vegetation ranges from bush, shrub forest to high forest (predominantly high thicket forest) (Siex, 2011).

Figure 1. Location of the study Shehias in the South District of Unguja Island.

Accordingly, the South District of Unguja is mostly dominated by *Albizia* and *Diospyros* species. In general, this natural vegetation is identified as part of the larger biodiversity hotspot of the East African Coastal Forests and is commonly known as habitat of the Zanzibar mini-antelopes and other wildlife populations. In very recent times, however, the natural vegetation cover has been modified by exotic species such *Casuarina equisetifolia* which are planted mostly for economic purposes.

Based on the Tanzania population census of 2012, the population in the South District of Unguja Island was 39,242 people in 2012 (URT, 2012). Out of these, 19,342 were men and 19,900 were women. The average household size was 4.2 persons. The sex ratio of the study area is 97 males to 100 females. The main primary economic activity in the South District of Unguja is agriculture. Shifting cultivation is the common method of farming because of the nature of the soil (Kukkonen and Kayhko, 2014). Other common economic activities in the study are commercial cutting of wood and fishing. Tourism, however, has recently emerged.

Research approach

This study applied the political ecology approach (Leff, 2012; Robbins, 2012) to explain land cover changes. Political ecology is basically an inquiry into the root causes of environmental/ecological decay (Robbins, 2012). It tries to understand the complex relations between nature and society from the decisions made at different levels, which impact forms of access and control over resources and their implications for environmental health and sustainable livelihoods (Misana et al., 2012). The approach is relevant to this study, since it provides an insight to the decisions made at different levels that have influenced land cover change of the study area. The approach emphasizes that land use/cover change results from complex interactions between society, reflecting economic, social and political processes, and the physical environment (Olson et al.,

Table 1. Characteristics of satellite images used in the study.

Sensor	Acquisition time	Spatial resolution	Path/Row	Producer
MSS	26/07/1975	60 m	178/064	USGS
ETM+	01/07/2009	30 m	166/064	USGS
Landsat 8	13/06/2014	30 m	166/064	USGS

Source: http://glovis.usgs.gov

2004). Based on this approach, the study has examined a myriad of socio-economic, political as well as physical drivers of land cover change since 1975 to 2014.

Data collection methods

The study required both spatial and non-spatial data as well as qualitative and quantitative data. Therefore, various methods of data collection were employed; these included acquisition of remotely sensed data and image pre-processing, structured interviews, key informant interviews and focus group discussions.

Acquisition of remotely sensed data and image pre-processing

Spatial data were obtained from Landsat MSS 1975, Landsat ETM 2009, and Landsat 8 2014 (Table 1). The selection of images was influenced by two aspects: periods which the study intended to cover and availability of cloud free Landsat images within the respective intended periods of the study. The study covered three periods, that is, before economic liberalization (before 1980s), post economic liberalization (1980 to 2009) and during implementation of Community Forest Management Areas (COFMA; 2010 to 2014), that corresponds with socio-political and economic decisions, which have determined the form of access and control of the natural resources. The cloud free Landsat images were available for 1975, 2009, and 2014. All the images were downloaded from Earth Resources Observation and Science (EROS) of the Geological Survey of the United States of America at http://glovis.usgs.gov. The Landsat images were selected over aerial photographs because the study intended to cover the entire South District of Unguja Island, which covers about 37,926.38 ha. The synoptic coverage of Landsat images (Lillesand et al., 2008) made them more advantageous than aerial photographs.

Two GIS software were used to analyze the selected Landsat images. These were Quantum Geographical Information System (QGIS) 2.8.1 and ArcGIS. The software were used in different stages of analysis. All the three Landsat images were first atmospherically corrected in QGIS 2.8.1 using Dark Object Substraction (DOS). In this operation, the digital numbers were corrected to actual surface reflectance. Then the images were re-projected in ArcGIS to Universal Transverse Mercator (UTM) zone 37 World Global System (WGS 84), south of the Equator standard. The satellite bands were then projected in true colour and then in false colour composite to visualize the images so as to identify land cover classes. Meanwhile, topo-sheets, aerial photographs of different years and the google earth images of the study area were also reviewed. The information from all sources was compared to identify the corresponding land cover classes (Table 2).

Supervised classification was used to create land cover maps. The process involved first, selection of training samples for each land cover class. The training samples were generated based on the researcher's experience and the reviewed information from google map, topo sheet and aerial photographs of the study area. After creating enough representative training samples, classification was performed by using maximum likelihood classification (MLC) tool in ArcGIS 10.1.

The next step involved application of majority filter tool to eliminate unclassified pixels. The majority filter (4×4) operation reduces the number of undefined pixels in the output map of a classified image. The pixel with a large value replaces the neighboring contiguous pixel to eliminate corruption of cellular patterns (Lillesand et al., 2008). Thereafter, the classified images were vectorised using 'Raster to polygon' tool. The operation was performed to convert images from raster format to vector format to correct parts affected by clouds.

Thematic accuracies for the 1975, 2009, and 2014 Landsat images were determined by the error matrix method in QGIS 2.8.1. For the 1975 and 2009 images, the level of accuracy was determined by creation of a region of interest (ROI) in Semi-automatic Classification Plugin (SCP) by using Multiple ROI tool to create new shape files. It involved selection of the number of random points, which represented different land cover classes. Then, the toposheet, aerial photos and google maps of the study area were used to identify and compare the determined points and the generated random points. All random points representing land cover classes were given values corresponding to the classified images (1975 and 2009) and the points out of the boundary (study area) were deleted to produce region of interest image. Then, the level of accuracy was determined by calculating the Error Matrix by using the Error Matrix Tool. The overall accuracies are shown in Table 3.

Accuracy assessment for the 2014 Landsat imagery was determined through ground truthing by using GPS points collected in 2015, which were used to create a shape file in the Arc GIS. Then, the ground truthing shape file was overlaid with the classified image of 2014 by using intersection tool to determine the level of accuracy (Table 3). These accuracies were within the minimum accuracy postulated by Anderson et al. (1976) for satellite-derived land use/cover maps.

The changes in various land cover categories were detected by overlaying maps and performing land use change detection. All polygons of the detected changes were assigned colour using colour nomenclature corresponding to their land cover classes. For clear presentation of change detection maps, however, only major changes were indicated in the legend of the change detection maps.

The study employed cross-tabulation to indicate the proportional quantitative changes. Using a field calculator, area in square hectares was calculated for each land cover class from which matrix tables of change detection and net changes were developed for each image. Summations of loss and gain were calculated to identify the net change for each land cover class. Then cross-classification (qualitative location of changes) was performed using intersect tool in the Arc GIS 10.1.

Structured interview

The structured interview method was used to collect socio-

Table 2. Description of land cover classes identified.

Land cover classes	Description
Dense forest	Land cover class consisting mostly of tall trees with some areas being impenetrable. The canopy cover ranges from 40 to 100%.
Shrub forest	Vegetative land consisting of small trees ranging between 2 and 8 m, with many branches, with dense foliage cover (70 to 100%)
Semi-open forest and bush	Land consisting of sparsely vegetated areas with natural, sparsely planted, or herbaceous vegetation and crop land. The natural semi-open forest and bush consists of very sparse, sparse to mid foliage cover
Built up/settlements	Built-up areas, roads or any other infrastructure
Open/Bare land	Open spaces with little or no vegetation, beaches, dune sands, bare rocks.
Sea/Water bodies	Water courses, water bodies, sea and ocean areas, coastal lagoons.

Source: Adopted from Klein and Kayhko (2008).

Table 3. Summary of the land cover classification accuracy.

Thematic images	Overall accuracy (%)	Kappa index
1975	92.58	0.88
2009	84.93	0.71
2014	94.20	0.88

economic data on factors influencing land cover changes in the South District of Unguja Island. The data were obtained by using a questionnaire containing closed and open ended questions, which captured the main economic activities of the people, land ownership, land cover change and causes of change. A total of 323 households were proportionally and randomly selected from six selected Shehias. Any member in a household who was 20 years and above was selected to represent the entire household. The elder members, including heads of household, however, were given priority. Gender involvement was also considered. The IBM Statistical Package for Social Sciences (SPSS) version 20 was used to analyse quantitative data from the socio-economic survey.

Focus group discussion

Six focus group discussions were conducted, one in each selected Shehia. The focus groups consisted of five to seven participants. The elders who were longtime residents were involved. A checklist of questions of interest was used to guide the discussions. The discussions were conducted to collect information such as the historical trends over time with regard to land cover changes and the causes of the changes. The content analysis method (Kitchin and Tate, 2000) was used to analyse the qualitative information from focus group discussions. The data were analysed during and after discussion. Themes were identified, compared and corroborated with literature.

In-depth interview with key informants

In-depth interviews were conducted on 13 key informants, who included six chairpersons/secretaries of community conservation committees, one from each selected Shehia, six local leaders (Sheha) one from each selected Shehia and one official from Department of Forestry and Non-renewable Resources. In-depth interview method was used to collect information about historical trends and causes of land cover changes. The content analysis technique was used to analyse information from in depth interview.

Transect walk and field observation

Transect walks were made along six transect lines of 1 km each, one in each of the selected Shehias to observe the real situation within the study area. The observation was, however, not restricted to the selected lines. Instead, the researchers were keen to observe the actual situation throughout the study area during field work. Information was collected independently through direct observation in the field without specifically asking questions to the respondents. During field observation, information such as human activities contributing to land cover changes and status of natural vegetation was collected. Data from field observation were recorded by using field note book and camera in the field. Field observation was made to complement both qualitative and quantitative data derived from the other methods.

RESULTS AND DISCUSSION

Patterns of land cover changes from 1975 to 2014

Summary statistics of land cover changes for 1975, 2009 and 2014 are shown in Table 4. The results reveal

Table 4. Summary statistics of area proportions of each land cover class and changes for 1975, 2009 and 2014.

Land cover type	1975		2009		2014		1975-2009	2009-2014	1975-2014
	Area/ha	%	Area/ha	%	Area/ha	%	Net change	Net change	Total increase/decrease (+/-)
Forest	16424.37	43.31	4371.93	11.53	5701.99	15	-12052.50 ha (-31.8%)	1330.10 ha (-3.5%)	-10722.4 ha (-28.3%)
Shrub forest	16581.08	43.72	20626.11	54.39	16488.35	43.5	4045 ha (10.7%)	-4137.8 ha (10.9%)	-92 ha (-0.2%)
Semi-open forest and bush	3998.47	10.54	11201.49	29.53	13143.07	34.7	7203 ha (19%)	1941.6 ha (5.1%)	+9,144.61 ha (24. 1%)
Open/bare land	380.91	1.00	365.24	0.96	220.56	0.6	-15.70 ha (-0.04)	-144.7 ha (-0.38%)	-0.4 ha (-0.001%)
Built-up/Settlements	34.98	0.10	503.58	1.33	1877.11	4.9	468.7 ha (1.2%)	1373.5 ha (3.6%)	4.8 ha (0.01%)
Sea	506.57	1.33	858.03	2.26	495.30	1.3	351.5 ha (0.93%)	362.7 ha (1.0%)	11.3 ha (0.03%)
Total	37926.38	100	37926.38	100	37926.38	100	-	-	-

considerable and fluctuant spatial changes over time, where some land cover classes declined while other land cover classes increased. Generally, forest declined by 28.3% from 43.31% in 1975 to 15% in 2014 (Table 4). Shrub forest slightly declined while settlements/built up area increased during the same time period. A major increase was observed in semi-open forest and bush, which increased from 10.54 to 34.7%. These results correspond to the findings of Kukkonen and Kayhko (2014) in Unguja Island and Solomon et al. (2018) in Wujig Mahgo Waren, Northern Ethiopia

This study has also revealed that since 1975, a large part of the forest has been transformed to shrub forest and semi-open forest and bush (Table 5 and Figure 2). Only about 4129.9 ha had remained as forest in 2014. Meanwhile, 331 ha of the forest were transformed to settlements/built up. These findings are contrary to the findings of Baral et al. (2018) who observed that approximately 60% of a total change in forest cover between 1995 and 2017 was gained from other land use land cover types in a typical Middle Mountain Watershed of Western Nepal.

Further analysis (Table 6) reveals that between 1975 and 2009, a large part of forest (10103.06 ha) changed to shrub forest, which increased from 16,581.08 to 20,626.11 ha. These findings imply that most of the shrub forest has resulted from the modification of forest. In addition, the analysis indicates that most part of shrub forest changed to semi-open forest and bushes.

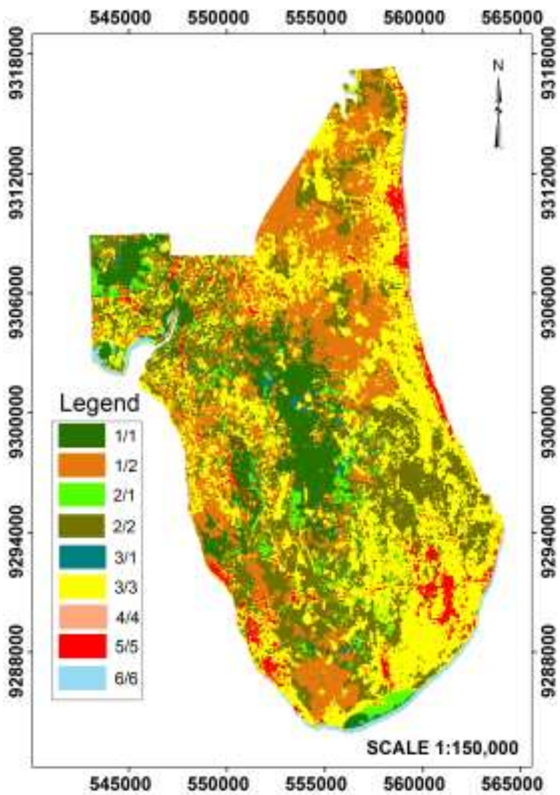
The preceding results generally imply that between 1975 and 2009, the extent of forest utilization was higher than the re-growth, consequently affecting forest morphology. Thus, most parts of the forest changed its form and became shrub. During the same period, some of the forest changed to semi-open forest and bush, open land, settlements/built up area and part was occupied by sea. These findings produce further evidence for the decline of forest, and they correspond with those of Kukkonen and Kayhko (2014) who reported that from 1975 to 2009, about 0.88 km^2 of forests in Unguja Island were lost annually, a total of 29.9 km^2 loss within 34 years.

A similar trend of forest loss was observed between 2009 and 2014 (Table 7) though at a reduced rate. Most parts of the forest changed to shrub forest and semi-open forest and bush. Nevertheless, the forest had a net increase of 1330.10 ha (+3.5%) (Table 4). A large part of the shrub forest (3018.77 ha) had changed to forest. The changes were probably influenced by the establishment of community forest management areas. These results concur with those of Cimini et al. (2013) who noted the spreading of forest and slight decline of shrub from 1989 to 2008 in the Mediterranean mountain landscape due to establishment of conservation areas that led to evolution of forest habitats in areas formerly covered by shrub.

Data in Table 7 further show that some parts of the shrub forest changed to semi-open forest and bush as well as settlements. Further analysis showed that shrub forest experienced the greatest decline of almost -11% (Table 4) between 2009 and 2014 indicating that it was the most utilized cover class. On one hand, the nature of vegetation makes it easy to be cut and cleared by using simple tools because there are no big trees involved. It is also simple to penetrate through it. Thus, it is easy to establish settlements, conduct farming and cut trees for firewood in the shrub forest. On the other hand, establishment of community forest management areas might have restricted people from over utilizing forest areas, thus making people turn to exploiting shrub forest. These findings correspond to those of Helmschrot

Table 5. Summary statistics of land cover changes for 1975 and 2014.

Year	2014							
	Land cover type	**Forest**	**Shrub forest**	**Semi-open forest and bushes**	**Open land**	**Settlements/built up area**	**Sea**	**Total**
1975	Forest	4129.9	8029.06	3864.3	7.3	331	62.8	16424.37
	Shrubs	1233.4	6979.23	7269.28	33.1	1060.3	5.76	16581.08
	Semi-open forest and bushes	319.5	1445.3	1799.08	38.1	352.7	43.8	3998.47
	Open land	1.89	23.96	116.16	91.3	123.6	24.02	380.91
	Settlements/built up area	0	2.2	19.33	2.36	8.08	3	34.98
	Sea	17.3	8.6	74.92	48.4	1.42	355.93	506.57
	Total	5701.99	16488.35	13143.07	220.56	1877.11	495.30	37926.38



Key	Description
1/1	Forest has remained the same
1/2	Forest has changed to shrub
2/1	Shrub has changed to forest
2/2	Shrub has remained the same
3/1	Semi open forest and bush has changed to forest
3/3	Semi open forest and bush has remained the same
4/4	Open/bare land has remained the same
5/5	Settlement has remained the same
6/6	Sea has remained the same

Figure 2. Land cover change between 1975 and 2014.

Table 6. Change detection statistics based on post-classification comparison between 1975 and 2009.

Year	2009							
	Land cover type	**Forest**	**Shrub forest**	**Semi-open forest and bushes**	**Open land**	**Settlements/built up area**	**Sea**	**Total**
1975	Forest	3498.6	10103.06	2578.4	61.4	58.51	124.5	16424.37
	Shrubs	650.23	8787.45	6867	81.42	161.12	33.87	16581.08
	Semi-open forest and bushes	216.91	1715.6	1698.94	103.51	171.15	92.35	3998.47
	Open land	2.44	2.84	38.11	116.95	102.81	117.75	380.91
	Settlements/Built up area	0	4.09	10.46	0.09	7.52	12.74	34.98
	Sea	3.75	13.07	8.58	1.87	2.47	476.82	506.57
	Total	4371.93	20626.11	11201.49	365.24	503.58	858.03	37926.38

Table 7. Change detection statistics based on post-classification comparison between 2009 and 2014.

Year	2014							
	Land cover types	**Forest**	**Shrubs**	**Semi-open forest and bush**	**Open-land**	**Settlements/built up area**	**Sea**	**Total**
2009	Forest	2345.11	1577.74	389.91	6.08	47.1	5.99	4371.93
	Shrubs	3018.77	12226.01	5036.31	10.93	333.07	1.02	20626.11
	Semi-open forest and bush	300.55	2575.15	7202.32	6.4	1104.48	12.59	11201.49
	Open-land	2.69	45.07	133.4	91.21	92.68	0.19	365.24
	Settlements/Built up area	0	39.43	158.93	10.72	294.31	0.19	503.58
	Sea	33.88	25.29	222.43	95.34	5.47	475.62	858.03
	Total	5701.99	16488.35	13143.07	220.56	1877.11	495.30	37926.38

et al. (2015) who also found that shrub land was declining in tradeoff with expansion of settlements and farms in Massili basin, Burkina Faso.

Generally, there has been fluctuation of different land cover from 1975 and 2014 in the South District of Unguja Island. The general trend of natural vegetation cover has been declined while settlements/built up areas have increased. These findings are supported by results from the questionnaire interview, focus group discussions, key informant interviews and observation. Most of the respondents (58.8%) in the questionnaire interview indicated that the natural vegetation cover ranged between 80 and 89% during 1970s and 1980s but declined slightly in the 1990s. Besides, most of the respondents (37.8%) disclosed that between 2010 and 2014, the natural vegetation cover had declined to between 40 and 49% (Table 8).

According to the respondents, the most declined land cover types were forest and shrubs while semi-open forest and settlements had increased. These findings imply that local people were aware that the natural vegetation cover had declined, while artificial land marks had increased. Orjala (2008) also noted that most of the informants in Zanzibar had noticed the decline of natural vegetation in their environment although they could not mention any specific year or decade when the decline had started. This, however, does not mean that the local people of Kiwengwa did not know the time when their environment changed. It might be that the methods used by Orjala could not capture information on the local people's perception of the period they had started to experience declining natural vegetation.

During focus group discussions members revealed that forest was previously very extensive and covered a large part of the coral rag natural

Table 8. Respondent's perception on percentage of natural vegetation cover between 2010 and 2014.

Vegetation cover (%)	20-29		30-39		40-49		50-59		60-69		Total	
Shehia	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Paje	1	1.5	10	15.4	33	50.8	15	23.1	6	9.2	65	100.0
Jambiani Kibigija	2	2.6	8	10.5	23	30.3	29	38.2	14	18.4	76	100.0
Mtende	0	0.0	13	19.4	25	37.3	20	29.9	9	13.4	67	100.0
K/Mkungunu	0	0.0	15	24.2	32	51.6	14	22.6	1	1.6	62	100.0
Kibuteni	1	5.3	4	21.1	2	10.5	8	42.1	4	21.1	19	100.0
Muyuni 'A'	8	23.5	16	47.1	7	20.6	2	5.9	1	2.9	34	100.0
Total	12	3.7	66	20.4	122	37.8	88	27.2	35	10.8	323	100.0

Source: Field Survey (2016).

Plate 1. An improved forest in Mtende following establishment of community forest management areas.
Photo taken by Said (2017).

vegetation. They further reported that the natural forest started to decline during 1990s, but the establishment of community forest management areas restored some of the degraded forest areas (Plate 1). During in-depth interviews one of the key informants in Paje narrated that,

"*Before 1980s, the forest in the south district was very extensive and very dense with big trees. But recently, most of the forest has declined and there are no big trees in many areas. A few big trees are found only in the conservation forest of Muyuni-Jambiani*".

Causes of land cover changes

Different factors have caused land cover change in the study area at different times. These include both direct and underlying causes, which are however inseparable; they function interdependently with each other to cause the observable land cover changes. These factors reflect the complex interactions among the economic, social and political processes, and the physical environment that have operated in the South Unguja District since the 1970s.

Direct causes of land cover change

Various human activities were found to directly cause land cover change in the South District of Unguja. These may be categorized as economic, including shifting cultivation, commercial cutting of firewood and charcoal making, commercial cutting of wooden pegs and cutting of sticks for sea weed farming, as well as social, mainly clearing of land for settlements (Table 9).

Majority of the respondents mentioned shifting cultivation as a causes of land cover change followed by commercial cutting of wood (mainly for fuel wood, charcoal making

Table 9. Respondents' perceptions on direct causes of land cover changes in South district of Unguja.

Direct cause	Cutting of sticks for seaweed farming		Clearing of forest for shifting cultivation		Clearing of land for settlement		Commercial cutting of wood		Total	
Shehias	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Paje	10	15.4	27	41.5	22	33.8	6	9.2	65	100.0
Jambiani Kibigija	15	19.7	23	30.3	17	22.4	21	27.6	76	100.0
Mtende	0	0.0	24	35.8	7	10.4	36	53.7	67	100.0
K/Mkungunu	0	0.0	24	38.7	24	38.7	14	22.6	62	100.0
Kibuteni	0	0.0	7	36.8	0	0.0	12	63.2	19	100.0
Muyuni A	0	0.0	19	55.9	0	0.0	15	44.1	34	100.0
Total	25	7.7	124	38.4	70	21.7	104	32.2	323	100.0

Source: Field Data (2016).

and wooden pegs) and settlements. Only a few mentioned cutting of sticks for seaweed farming. Fujiki et al. (2018) explain that shifting cultivation in tropical regions has remained as the widespread cause of land cover change.

Shifting cultivation

Shifting cultivation has been a traditional agricultural practice in the coral rag zone of the South District of Unguja. The system involves slash and burn of the forested land to maintain or increase crop production until the nutrients in the soil are exhausted then the site is abandoned to recover (Chakravarty et al., 2012). The farmers move on to clear more forest.

During the survey, majority (73.4%) of the interviewed respondents reported that they frequently cleared the forest to access new farm plots or expand their farms because of deterioration of the soil in their old farms. This is an indication that most people in the study area practiced shifting cultivation because of declining soil fertility in their farms. This finding was confirmed during the transect walks, in Muyuni 'A', Mtende, Kibuteni and Jambiani Kibigija where most of the forested lands had been cleared for cultivation (Plate 2). The findings correspond with those of Masoud (2003) who reported that shifting cultivation had become one of the main factors that contributed to deforestation of the coral rag forest in the South District of Unguja.

The findings of this study further revealed that majority of the respondents (64.1%) had shifted to new farms within the last three years (since 2013 to 2016). Jambiani Kibigija and Kibuteni had the highest number of households who had shifted to new farms (Figure 3). These findings concur with those of Nzunda et al. (2013) in Bukoba-Tanzania. Heinimann et al. (2018) has also confirmed that shifting cultivation is still present in many of African countries.

As a result of shifting cultivation, most of the forested land in the study area has been cleared for new farms. There was a statistically significant positive correlation between deforested land and accessed new cultivated land at 0.05% level of confidence with a Pearson Correlation value of 0.564**. These findings indicate that most of the new farms were accessed from forested land. Therefore, as the cultivated land increased, deforestation and fragmentation also increased. This is supported by data from satellite images, which show that 3864.3 ha of forest and 7269.28 ha of shrub were transformed to semi-open forest and bushes (Table 5).

During key informant interviews in all the Shehias it was revealed that based on their by-laws, the local people were required to cultivate their farms for not less than three years, after which, they could request for new farms, locally known as *chenge*, from the conservation committee. Three years of cultivation '*kulima chenge'* have been agreed upon to reduce clearing of natural vegetation. Besides, during the focus group discussions, the participants in all Shehias revealed that most of the people normally engaged in shifting cultivation because the coral rag land does not support cultivation in one area for more than 2 or 3 years.

In general, the practice of shifting cultivation in the study area give an indication that soil fertility in the study area declines rapidly after the land has been put into cultivation; hence, the farmers frequently shift to new farms to maintain crop production. The farmers probably do not use any inputs to improve land productivity. Consequently, more often than not, natural vegetation is removed, thus contributing to changing the physical pattern of the landscape. As Kukkonen and Kayhko (2014) reported Zanzibar has lost most of her natural forest since 1996; most of which has been replaced by cultivation.

Commercial cutting of fuel wood and wooden pegs

Commercial cutting of fuel wood (fire wood and charcoal) and wooden pegs were found to be among the common income generating activities to some people in the South District of Unguja. Although the findings of the study

Plate 2. An area that has been cleared for shifting cultivation in Jambiani Kibigija.
Photo taken by Said (2017).

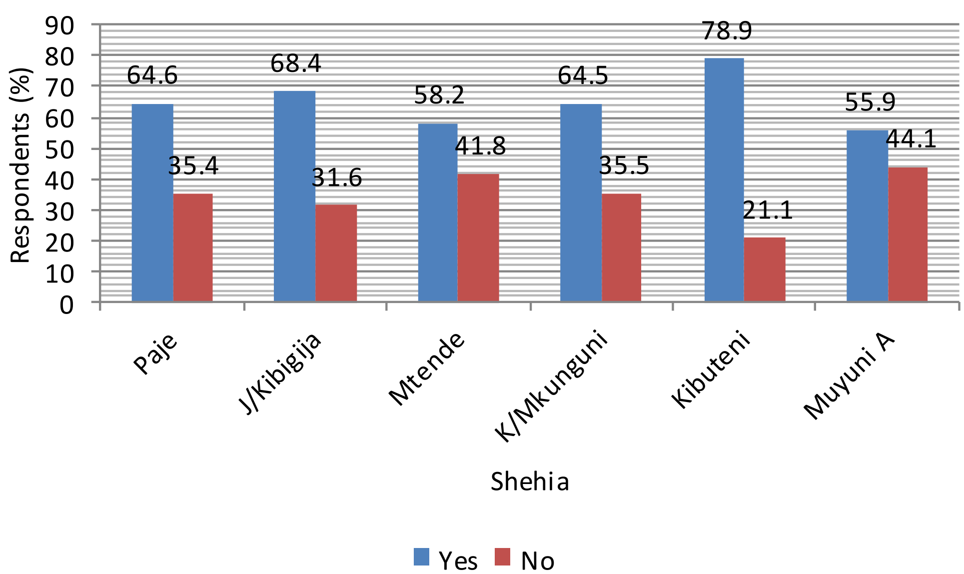


Figure 3. Respondents who had shifted to new farms through shifting cultivation since 2013 to 2016.
Source: Field survey (2016).

revealed that only a few respondents (27.6%) were involved in commercial cutting of wood, its contribution to land cover change was apparently observable. Majority (77.5%) of those respondents who were involved in commercial cutting of wood products were involved in cutting trees for fire wood (Table 10). In all the Shehias, the number of respondents who were involved in fire wood cutting was high when compared with charcoal making and cutting of wooden pegs. This is probably due to the high demand of fire wood in the South District of Unguja and the urban west. RGoZ (2013) reported that the main source of energy in Zanzibar was firewood and that more than 90% of the people used fuel wood as their main source of energy for cooking. Most of the fire wood

Table 10. Respondents involved in commercial cutting of wood for fire wood, charcoal making and wooden pegs.

Shehia	Firewood		Charcoal		Pegs		Total	
	n	%	n	%	N	%	n	%
Paje	7	77.8%	2	22.2%	0	0.0%	9	100.0%
Jambiani Kibigija	21	87.5%	3	12.5%	0	0.0%	24	100.0%
Mtende	12	85.7%	2	14.3%	0	0.0%	14	100.0%
K/Mkungunu	10	83.3%	2	16.7%	0	0.0%	12	100.0%
Kibuteni	7	53.8%	2	15.4%	4	30.8%	13	100.0%
Muyuni A	12	70.6%	2	11.8%	3	17.6%	17	100.0%
Total	69	77.5%	13	14.6%	7	7.9%	89	100.0%

Source: Field Survey (2016).

was being extracted from the coral rag forest in South District of Unguja (*ibid*).

The study also found that those who were involved in commercial cutting of fire wood have been cutting many bundles when compared with those collecting fire wood for domestic use. The mean number of bundles of commercial fire wood cut in a month was 22.56 while that of bundles collected for domestic use was 4.92. Similarly, the maximum number of bundles for commercial fire wood exceeded that for domestic use. During field observation, many bundles of fire wood were found along the main road ready to be transported to town.

Commercial cutting of wood involves mostly cutting of live trees, which is generally unsustainable. This has, to a large extent, contributed to forest degradation and fragmentation of the coral rag forest. During in-depth interviews in Kibuteni, one of the key informants narrated that,

"Commercial cutting of wood is common in our Shehia. Many people both males and females are involved in cutting of tree for fire wood, charcoal and wooden pegs, which are mostly transported to town. Some of them pile their products along the road for selling. Commercial cutting of fire wood, charcoal and pegs has caused forest degradation because many trees are being cut".

As for charcoal making, only 14.6% of the respondents who were involved in commercial cutting of wood were involved in charcoal making. Despite the fact that charcoal making was conducted by few people, its impact on the natural vegetation was apparent. Many areas in the forest reserve were found degraded by charcoal making. During field observation, some charcoal bags were found in the Muyuni-Jambiani forest reserve.

Charcoal making in the forest does not only cause degradation but also it destroys the biodiversity of a place (FAO, 2017; Arnold and Persson, 2003). Sangay (2011) maintained that unrestricted harvesting of vegetation for fuel wood and charcoal may exceed biomass growth, thus resulting in declining supplies and forest degradation. During key informant interviews, it was revealed that most of the harvestable trees have been cut for fire wood, charcoal making and wooden pegs. As such people have now started to cut trees that are not ready for harvesting. Meanwhile, there is no control or limit on the number of fire wood bundles a person is allowed to cut per month and the size of trees to be utilized. Therefore, uncontrolled utilization of the forest has resulted to forest decline and degradation.

The study also found that some respondents were cutting wooden pegs for commercial purpose, though the number was small (7.9%). Commercial cutting of pegs was mostly being carried out in Kibuteni and to a lesser extent in Muyuni 'A' (Table 10) probably because of limited economic opportunities for the people to earn their living. Although few respondents were involved in commercial cutting of wooden pegs, many bundles were being cut because they were highly in demand in the urban areas. The coral rag forest of the South District is the only main repository source of wood products in the Island. Therefore, it is faced with over utilization, which leads to land cover change.

Clearing of land for settlements

Findings from the questionnaire interviews revealed that about 21.7% of the respondents reported that clearing of land for settlements had caused land cover change in their locality (Table 9). This was mostly reported in Kizimkazi Mkunguni, Paje and Jambiani Kibigija. These findings are supported by data from satellite images and GIS analysis, which indicate that built up area/settlement increased from 0.1% in 1975 to 4.9% in 2014. About 331 ha of forest and 1060.3 ha of shrubs had changed to settlement during the same period. Probably, the expansion of settlements in those Shehias, among other things, was contributed by development of the tourism sector.

During key informant interviews, it was revealed that settlement expansion had contributed to clearing of natural vegetation. One of the key informants in Paje narrated that, *"Our village is expanding very fast because our population is increasing and thus people's demand for land for constructing houses is increasing too. Therefore, we have allocated areas for settlement, although some of the people do not follow the procedures. Instead they just clear natural vegetation and establish settlement wherever they like*".

Expansion of settlements has been reported to cause forest decline in many areas particularly in developing countries (Alemayehu, 2016; Hariohay, 2013; Ouedraogo at al., 2010). For instance, Alemayehu (2016) reported that settlement expansion had contributed to natural vegetation decline along the coastal areas of Kenya. Similarly, Hariohay (2013) found that settlements expansion caused forest decline and fragmentation of the wildlife migratory passage in Kwakuchinja wildlife corridor in Northern Tanzania.

Cutting sticks for seaweed farming

Commercial seaweed farming has also been found to increase pressure on forest resource utilization. Seaweed farmers cut bundles of sticks for seaweed growing thereby degrading the forest. Since 1989, seaweed farming in Zanzibar has been one of the sources of income particularly to the communities living near the coastal areas (Msuya, 2012). Today Zanzibar is the ninth world producer of sea weeds contributing about 0.63% of the world's seaweed production (Radulovich et al., 2015). Seaweed farming has, however, been contributing to forest degradation in areas where it is being carried out. Among other places, Paje, Jambiani and Bwejuu were found to be the major seaweed producers; hence the natural vegetation in their locality had been affected to a large extent by cutting of sticks. About 19.7 and 15.4% of the interviewed respondents in Jambiani and Paje, respectively, revealed that cutting sticks for seaweed farming had significantly contributed to rapid decline of natural forest in their locality.

During in-depth interviews, key informants in Jambiani Kibigija and Paje revealed that seaweed farming had greatly contributed to decline and degradation of the forest because seaweed farmers cut bundles of sticks, which they used for growing of seaweed. Cutting of sticks was being done in every season of seaweed growing. One of the key informants in Jambiani Kibigija narrated that,

"*Many of the trees nearby have been cut for getting sticks, which are used for growing seaweed. Nowadays, people walk a bit long distance for cutting sticks and some of them buy from other people. Women are the ones who mostly cut sticks for seaweed growing*".

Many bundles of sticks were being used for one growing season (six months) by farmers, after which other sticks would be cut for the next growing season. Msuya (2012) reported that some farmers employed fellow villagers or villagers contracted themselves out to farmers to cut and sell sticks for seaweed farming. Cutting of large quantities of sticks repeatedly results in low plant succession that leads to changing the natural vegetation cover from forest or shrubs to semi open forest and bush. Arnold and Persson (2003) explained that continuous cutting of wood can lead to transformation of forest/woodland to bush, and bush to scrub, over very large areas.

Underlying causes of land cover changes

Several underlying factors have been found to cause land cover change at different times in the South District of Unguja. These include population growth and population density, policy reforms and policy failure, land tenure insecurity and the nature of the soil and terrain. These again are a reflection of the social and political processes as well as the natural environment that operate in the district.

Population growth and population density

Population growth and increasing population density are among the major underlying causes that have influenced the utilization of land, forest and other natural resources in the South District of Unguja resulting in land cover change. Population growth contributes to land cover changes in two ways, firstly, through population pressure within the district and region and secondly through population pressure from the urban-west region.

The population of South District of Unguja has been increasing gradually from year to year. The census data indicate that between 1978 and 1988, the population of the South District of Unguja grew at 1.3% (NBS, 1989). The growth rate, however, decreased to 1.1% between 1988 and 2002 and increased to 2% between 2002 and 2012 (NBS, 2006; URT, 2013). The number of people has grown from 21,952 in 1975 to 39,242 in 2012 (NBS, 1989; URT, 2013). Because of the population growth from both natural increase and immigration, the population density has steadily increased from 56 persons/km^2 in 1978 to 100 persons/km^2 in 2012 (Figure 4). Such population growth and increased densities have led to increased demand for land resulting in land scarcity and expansion of agricultural land and settlement into the forested areas. This has subsequently led to forest decline and fragmentation.

Furthermore, the growth of population in the urban-west of Unguja has also been found to increase pressure on the coral rag forest resource of the South District of Unguja. The population of urban-west has increased dramatically from 208,389 in 1988 to 593,678 in 2012

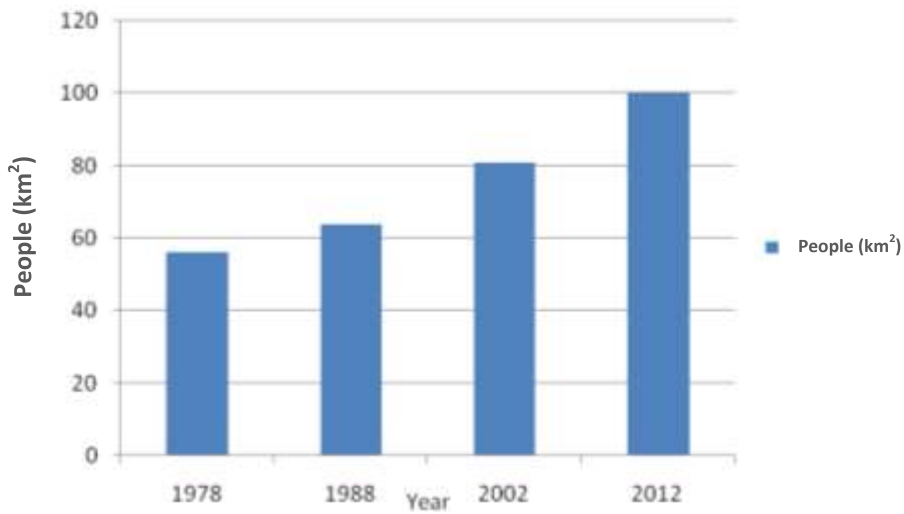


Figure 4. Population density of South District of Unguja between 1978 and 2012.
Source: NBS (1989), NBS (2006), and URT (2013).

(URT, 2013; NBS, 2006). Such an increase of population has led to increased demand for fire wood, charcoal and wooden pegs. This is because the population of urban-west of Unguja has provided a reliable market of wood products. Fuel wood is not only utilized for domestic purpose but it is also being used in hotels and bakeries (RGoZ, 2012). The coral rag forest supplies much of the fuel wood and building materials to the majority of the population in the urban-west. It has been found that hundreds of bundles of fire wood and wooden pegs are transported from the South District of Unguja to the urban market every day. Actual records, however, are missing because there is no monitoring of the amount of wood being cut and transported to the urban market. Nevertheless, such high demand for wood has triggered several individuals in the study area to engage in commercial cutting of wood materials resulting in forest degradation and decline. These results are in line with those of Mwangi et al. (2017) and Alemayehu (2016) who also found that population growth was one of the main causes of land cover change in Kenya.

Land tenure insecurity

Land cover change has also been influenced by land tenure insecurity. Many individuals lack security of tenure of their lands due to political decisions made. In Zanzibar, land is a public property; the powers to decide on the use of land are vested in the President for the interest of the public. The government, however, has established different Acts including the Land Distribution Decree (1966) and the Land Tenure Act 1992 to protect the land and to give individuals the right to use land to improve their livelihoods (RGoZ, 2012). For instance, the Land Distribution Decree (1966) was amended to grant an individual the right to own land on leasehold for periods not exceeding 99 years (*ibid*). Such decisions have influenced the form of access and control of land resources. Despite the existence of such legal systems of land tenure, only few people in the study area particularly investors have this type of land lease. Many of the people have no title deeds; they own land just by traditional ways of written paper that has been endorsed by a community leader. Besides, most people have not acquired land officially from the government office.

During the household survey, it was found out that majority of the respondents had acquired land informally. For example, 77.8% had acquired land just by clearing the forest, 19.2% had inherited it from relatives and 2.8% had borrowed land either from relatives or friends. These findings are in support of those by Tilumanywa (2014) who noted that most of the rural people obtained land through informal ways including inheritance and borrowing. They are, however, contrary to those of Zahor (2014) who found that the majority of respondents (41.1%) in Ngezi had acquired land by inheritance.

The informal system of acquiring land does not guarantee security to majority of land owners. Such a tenure system has restricted land improvement by the majority of people. The Land Tenure Act 1992 specifies that all land is vested in the president for the use and common benefits of the people of Zanzibar (RGoZ, 2012). As such, many people are worried about developing their lands for fear of losing them. Thus, they mostly use them for farming.

Since 2010, the communities in the South District of Unguja have entered into contracts with the government to conserve the forest and land resources. The contracts give the community the right to plan, utilize and conserve their land but do not give an individual the right to own land permanently. Decisions on land are being made by the community leaders. Hence, during key informant interviews it was found that any community member who wished to get land for cultivation had to request from the conservation committee for a permit to cultivate. The member would be given not more than 1.2 ha (3 acres) for cultivation purposes not otherwise. However, there were many community members who just cleared vegetation without asking for permission, leading to land cover change. Although the decision made aimed to control shifting cultivation, it resulted into transformation of some forested areas to farms.

Policy reforms and policy failure

Land cover change in the South District of Unguja has also been influenced by policy reforms and policy failure. Based on the political approach, one can say that the growing diminish of natural vegetation cover is caused by both national and transnational decisions on policy reformation, which has influenced the forms of access and control of resources. Since 1964 after the Zanzibar Revolution, the Revolutionary Government has carried out various reforms of her policies such as the economic policy, land policy and environmental policy to improve people's livelihoods as well as facilitate proper management of environmental resources. However, some of these policy reforms, particularly those related to the tourism investment policy and the natural resources and environmental policy have brought unintended outcomes to the natural resources, including alteration of the natural cover of the Island.

Tourism investment policy

During the mid-1980s, Zanzibar as part of the United Republic of Tanzania started to implement various structural adjustment programmes under the influence of the International Monetary Fund (IMF), World Bank (WB) and other bilateral donors (RGoZ, 2010). The reforms transformed Zanzibar from socialist economy to free market economy. During the socialist economy, the government was the custodian of operations and provision of economic services. Following the major economic reforms, the government enacted the Private Investments Promotion and Protection Act in 1986 which enabled local people to collaborate with foreigners to participate in tourism investment (Hikmany, 2016).

Since then, the coastal landscape zone of some villages in the South District of Unguja has experienced rapid changes from development of the tourism industry. The industry has caused an influx of people, expansion of settlements and construction of hotels and bungalows. The government also introduced Tourism Zoning Plan under the National Land Use Plan (NLUP) Policy of 1996 to develop sustainable places for tourism (Hikmany, 2016). It proposed 19 areas in Unguja with a total area of 400 ha and 6 areas in Pemba covering a total area of 83 ha. The construction of hotels, however, has been more rapid than it was planned. For instance in the 1990s, the south district of Unguja had only 18 tourism hotels, but this number had increased to 135 in 2016. According to Hikmany (2016), there was an increase of tourism accommodation in Zanzibar beyond the planned carrying capacity. For example, by 2011, the Commission for Tourism had 12,395 bed capacity as compared to the planned capacity of 6,000 beds for the whole of Zanzibar.

The construction of hotels and bungalows has increased the demand for land and wood products, leading to natural vegetation decline. Most of the interviewed respondents in Paje (73.8%) and Jambiani Kibigija (68.4%) revealed that tourism had highly contributed to land cover changes. In Kizimkazi Mkunguni, however, majority of the respondents (53.2%) said that tourism had little contribution to land cover change because only a small area of natural vegetation has been cleared for construction of hotels and bungalows. Many local people along the coastal areas in Paje, Jambiani and Kizimkazi have sold their land to investors for construction of hotels. Thus, they have had to find new lands for settlement. Most of them have established their new settlements towards the forest. Thus, despite the fact that the tourism industry was introduced in order to achieve economic growth while maintaining environmental health, it has been observed to contribute to over utilization of forest resources leading to their decline and land cover change.

Natural resources and environmental policies

Several legislative attempts on conservation of forests have been initiated in Zanzibar including the Constitution of the Revolutionary Government of Zanzibar (1984), the Commission for Lands and Environment Act, 1989, the Land Tenure Act 1992 and Forest Resource Management and Conservation Act 1996. However, despite these efforts, the natural vegetation has continued to decline gradually, with the forests being increasingly degraded and fragmented.

In 2010, a new form of community participation in forest management was introduced under the Forest Resource Management and Conservation Act 1996. The new approach recognized that there must be incentives to the community for sustainable and fair management of forests. Thus, the approach involved the establishment of Community Forest Management Areas (COFMAs) under the ''*Hifadhi Misitu ya Asili*'' (HIMA) project. Although, these conservation areas have been established to conserve natural forests, forest decline and fragmentation has continued to take place, unabated.

In addition, COFMAs involved demarcation of utilization areas where people were allowed to cut wood for their livelihood so as to preserve the established community conservation forests. This, however, has given rise to uncontrolled harvest, with every member of the community wishing to maximize utilization due to lack of clear guidelines for controlling over utilization. Besides, some of the designated community conservation areas form discrete parcels of conservation land because there was no universal conservation plan for the whole district; every community had their own conservation plan. Such conservation plans do not provide for continuous natural vegetation, which is important for biodiversity conservation. To a large extent, fragmentation of natural vegetation has been increased.

Nature of the soil, underlying rocks and the terrain

The nature of the soil, the terrain and underlying rocks are also driving factors of land cover change in the study area. These factors have been found to influence largely the clearing of vegetation and extraction of large quantities of wood materials resulting in forest decline and degradation.

Most of the underlying soil of the South District of Unguja is categorized as maweni soil (rendzic and lithic leptosols) (RGoZ, 1983). The soil has a high organic carbon content (about 20.3%), an alkaline pH (about 8) with high infiltration (Epper, 2015). Besides, the soil is drained, porous with a shallow profile; it does not store water (*ibid*). Thus, it is so susceptible that it loses nutrients easily when it is exposed to clearing of vegetation. Once the natural vegetation is cleared for cultivation, the soil becomes more drained and it hardly takes two to three years to support crop production. Then, the farmers have to shift to other areas where they clear more forest to prepare new farms. Nyawira et al. (2017) maintain that when natural vegetation is cleared, the soil loses carbon, which is important for soil decomposition. Therefore, for the soil to recover, it depends on the local soil conditions such as soil type, mineralogy, texture and on climate influences, such as good temperature and good soil moisture or precipitation (Nyawira et al., 2016).

The soil condition has become more critical currently than ever before because of the unreliable rainfall arising from climate change. The rain fall seasons are mostly short followed by long dry seasons, thus the soil lacks enough moisture to support productivity. This situation drives people to frequently clear natural vegetation cover to find virgin land to maintain their crop production. Subsequently, the repetitive clearing of forest for shifting cultivation has resulted in forest decline and fragmentation.

Apart from the soil condition, it was observed during the transect walks that most of the study area was flat and characterized by coral rag rocks. This is also supported by Klein and Kayhko (2008) and Hettige (1990) who described the southern part of Unguja Island as being mostly flat lying Quaternary coral rag of low altitude, whose altitude almost ranges between 0 and 30 m above sea level and only few areas elevate between 30m and 60m.

Because of the nature of the terrain, most of the remote forested areas within the study area were being accessed by motor vehicles, oxcarts, and bicycles. The flat lying nature of the landscape and the underlying coral rag rock allow driving, cycling and oxcarts movement throughout the year because of lack of steep slopes. Secondly, the underlying coral rag rocks reduce mud during rain seasons; hence, the area becomes accessible throughout the year. Thus, the nature of the terrain and the underlying rock do not create barriers for transportation of wood materials from remote areas, instead it supports extraction of large quantities of wood all the time.

Conclusion

Major changes of land cover have occurred since 1970's in the coral rag vegetation of the South District of Unguja Island. The major change has been forest decline and increase of semi-open forest and bush. Several factors have caused land cover changes in the study area at different times. These include direct causes such as shifting cultivation, commercial cutting of wood products (fire wood, charcoal and pegs), clearing land for settlements and cutting sticks for sea weed farming as well as indirect causes such as population growth, policy reforms and failure, land tenure insecurity and the nature of the soil, terrain and underlying rock of the study area. Since majority of the people depend on the coral rag ecosystem for their livelihood and the fact that the ecosystem is the only wildlife habitat within the island, continued changes of land cover may affect either negatively or positively wildlife populations and their habitats as well as the livelihoods of the communities.

Given the limited sources of income for the majority of the local people as well as the limited alternative sources of cooking energy in the Island, the natural vegetation will continue to decline because of over utilization by both the rural and urban population. There is therefore need to invest in intensive agriculture to reduce shifting cultivation. It is also important to allocate areas for establishment of plantations for cooking energy to reduce over exploitation of natural vegetation. As a long term solution, the government needs to invest in alternative sources of energy. The Island is located in the tropical area where there is opportunity to invest in solar and wind energy. Possibly, the Indian Ocean waves may also provide reliable energy for the Island. Because, the coral rag vegetation is recognized as an important and the only remaining wildlife habitat within the Island, there is need to undertake studies to assess the impact of land cover change on the wildlife population and habitat so as to devise appropriate conservation strategies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Structure and natural regeneration of woody species at central highlands of Ethiopia

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The management of regeneration plays a vital role in sustainable forest practice by ensuring the future growing carbon stock and serving as an indicator of the forest condition of an area. In premises of the above-mentioned facts, the current study was conducted to investigate the population structure and regeneration status of woody species as an indicator for forest condition and to provide information on sustainable management of the woody plants in Chilimo-Gaji Forest. The data collection was done using a preferential sampling technique as a sampling design and a total of 36 plots with a size of 20 m × 20 m (400 m^2) was laid out for the woody species. In each sample plot, all woody species seedling, sapling and mature tree/shrubs were counted and recorded. And their diameter at breast height (DBH) was measured at 1.5 from the ground with DBH ≥ 2.5 cm. A total of 42 species of vascular plants belonging to 34 genera and 28 families were recorded and identified from the 36 study plots. The total density of woody plant species in all the 36 sampled plots of the study area was 3328.47 individuals ha^{-1}. The total density of seedlings, saplings and trees/shrubs were 1743.75, 827.08 and 757.64 ha^{-1}, respectively. The regeneration status of individual tree species showed differences as 26% had good regeneration, 43% had fair regeneration, 7% had poor regeneration, 7% lacked regeneration, and 17% have appeared as newly regenerating. The cumulative species DBH class distribution of the study area was inverted J-shape distribution indicating stable population status or good regeneration status.

Key words: Chilimo-Gaji, Dry Afromontane, regeneration, vegetation structure.

INTRODUCTION

Natural resources are an integral part of society and natural ecosystems as an integral part of the renewable natural resources serving as a major sustainable development index for each country. Natural tropical forests are extremely important for the conservation of the world's biological diversity. Forests play an important role in supporting the livelihood of people worldwide, predominantly in meeting the daily subsistence needs of the world's poor (UNFF, 2007; Siraj et al., 2016), served as refuges for human beings during wars and for other

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flora and fauna (MEA, 2005), acting as carbon sinks (Aune et al., 2004), contributing to soil and water conservation (FAO, 2014) as well as maintain soil quality. The Afromontane areas of eastern Africa, including the Ethiopian highlands are known exceptionally for their species richness, high concentrations of endemic species. However, these areas are under excessive human land-use pressure (Gebrehiwot and Hundera, 2014). These Afromontane ecosystems are the most threatened ecosystems in the country due to conversion of natural forests to agricultural land and other uses, commercial logging and loss of biodiversity (Tesfaye et al., 2016). The reduction of vegetation and environmental degradation has become issues of national and global concern in recent years. Losses of forest resources at an alarming rate have an implication regarding biodiversity, climate, environment and socio-economic status of a country (Aliyi et al., 2015).

Ethiopia is a country located in the Horn of Africa, characterized by greatly varying landscapes such as rugged mountains, river valleys, flat-topped plateau, deep gorges, and rolling plains. The country is also known for its tremendous wealth of natural resources and biological diversity, scattered over the highest altitudinal ranges from the peak of mountains to one of the lowest and hottest places on earth; however, it faces serious conservation challenges as the result of population increase and land use changes. Ethiopia is the second most populous African country next to Nigeria with the population growth rate among the highest in the world, currently estimated at 2.5% per year (World Bank, 2015). This increase of population at an alarming rate has resulted in rapid and widespread conversion of forest habitats for human settlements, clearing for agriculture, charcoal and firewood harvesting (Bekele, 2011; Campbell, 1991; Buechley et al., 2015), causing habitat fragmentation into smaller pieces of forest of patches. The process of forest fragmentation due to human activities that break large contiguous forested areas through logging or conversion of forests into agricultural areas and suburbanization (Forman, 1995) has been identified as the most important factor contributing to the decline and loss of species diversity worldwide (Bogaert et al., 2011; Noss and Cooperrider, 1994). Forest destruction and fragmentation increase the vulnerability of forest tree community disturbances (Benitez and Malvido, 1998), affecting regeneration of the forest.

Natural regeneration is a fundamental component of tropical forest ecosystem dynamics and is essential for conservation and maintenance of biological diversity (Rahman et al., 2011; Getachew et al., 2010; Dutta and Devi, 2013) as well as to identify plant species for conservation priority; whereas, population structure plays a significant role in determining the dominant status of tree species and development within the forest stand. Regeneration is a key process of building a forest by which trees and forests survive, substitute or restore (Tyagi et al., 2013). Management of regeneration is an essential component of sustainable forest practice as it ensures the future growing stock (Level, 2010). The knowledge of the floristic composition, regeneration, population structure of a plant community is a prerequisite to understand the overall structure and function of any ecosystem (Singh et al., 2016), whereas understanding woody species diversity and socio-economic factors causing devastation of natural forests ecosystem is crucial in the management of the remnant forest ecosystems (Yakob and Fekadu, 2016). Therefore, it is important to study the floristic composition, population structure and regeneration potentials of different natural forest tree species in Chilimo-Gaji Forest to assess the trends of vegetation in the future. The future composition of forests depends on potential reproduction and recruitment as regeneration status of tree species within a forest stand in space and time (Eilu and Obua, 2005; Henle et al., 2004).

The patterns of regeneration is important because it will ultimately determine the floristic composition of the remnant (Laurance et al., 1998). The density value of seedling and saplings are considered as an indicator of regeneration potential of the species (Arya and Ram, 2011) in which the presence of good regeneration indicates the suitability of a species to the environment, which is in turn affected by climatic factors and biotic interference influence (Dhaulkhandi et al., 2008). The successful regeneration of woody tree species is mainly dependent on a function of three major components: (i) their ability to initiate new seedlings, (ii) the survival ability of seedlings and saplings and (iii) the growth ability of seedlings and saplings (Good and Good, 1972). The density, composition of species and regeneration drives the future of forest which is in need of replacement; and however faces several regeneration stressors including invasive alien species, insects and diseases, herbivory, lack of appropriate management and climate change (McWilliams et al., 2015).

Uncontrolled encroachment and exploitation of natural resources has reduced the coverage of forests, the density and diversity of trees in the forest in Ethiopia leading to deforestation and degradation. Unlike homogeneous plantations, management of natural forests largely depends on successful natural regeneration of valuable species (Islam et al., 2016), which occur when the trees establish and develop as part of the stand.

The forest management paradigm in Ethiopia has recently shifted from conventional management approach to community based participatory forest management under protected area management scheme. Successful management and conservation of natural forest requires reliable data on aspects such as the regeneration trends (Eilu and Obua, 2005). Forest stand, where there are numerous young individuals and lesser mature ones, is recognized as having an inverse J-curve diameter distribution (Dyakov, 2013).

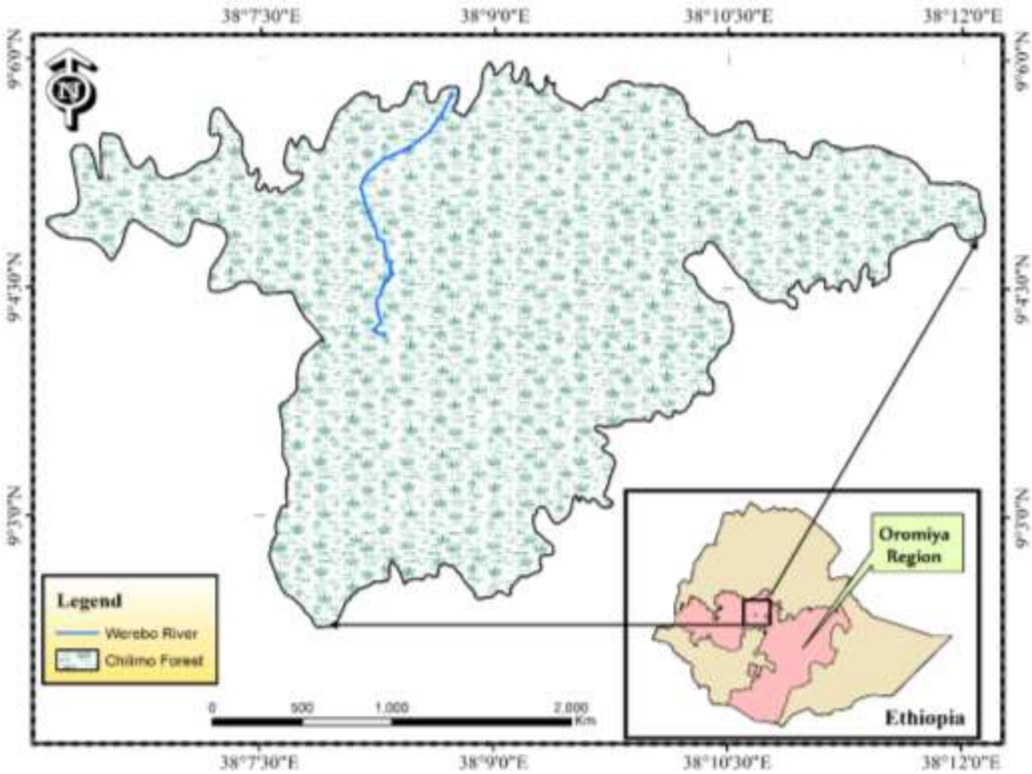

Figure 1. Map of the study area.

MATERIALS AND METHODS

Description of the study area

The present study was conducted in Chilimo-Gaji Forest which is among the few remnant patches of native dry Afromontane Forest in the country (Figure 1). The forest is located in the Dendi district, which is one of the districts endowed with different landscapes in Oromia Regional State, near to the small town of Ginchi. The study area geographical location is 38° 10' E, and 9°05 'N and with altitudinal ranges between 2170 to 3054 m a.s.l. The forest is a small enclave in the western section of the ridge that stretches from the capital westward to Gedo highlands (Soromessa and Kelbessa, 2013). Chilimo-Gaji Forest consists of over 180 bird species, 21 mammal species commonly Menelik's bushbuck, vervet monkey, Colobus monkey, Anubis baboon and Leopard (Woldemariam, 1998) and other forest creatures are abundant.

Chilimo-Gaji Forest was designated as a national forest priority area in 1982 and is among Ethiopia's 58 national priority forest protected areas in order to minimize deforestation. Due to continuous deforestation, the Chilimo-Gaji Forest cover has declined from 22,000 ha in 1982 to 6000 ha in 1991 (Dugo, 2009). Currently, the forest cover area is estimated at about 5,000 ha, owned by the Federal Government. Though the forest is owned by the state, it is currently divided into blocks and managed by the local forest user groups forming cooperatives under the participatory forest management arrangement schemes. This type of forest management in many regions is assumed to be acting to improve forest conditions and the livelihood of the forest user groups. Chilimo-Gaji Forest is the pioneer of participatory forest management site in Ethiopia, where the forest user groups managing the forest have formed a strong cooperative union. The forest is important to these local people for grazing, firewood, as source of water, and construction materials. Participatory forest management focuses on improving the livelihood and conserving natural forest systems through local participation and cooperation. Participatory forest management can deliver multiple outcomes such as carbon storage, livelihood benefits and biodiversity conservation (Agrawal and Angelsen, 2009) and can lead to sustainable use of forest resources.

Geology and soils

In the central plateau including Chilimo-Gaji Forest, basalt constitutes the main rock types that are chemically and mineralogically uniform in composition (Soromessa and Kelbessa, 2013). The soils in Chilimo-Gaji Forest area are reddish brown, gravelly and shallow at higher altitudes, while at lower sites they tend to become dark-grey and deep; whereas soils in the surrounding low plains are vertisols, black soils with characteristic high clay content (Tesfaye et al., 2016). The major soil types around Chilimo-Gaji Forest areas are various types of Vertisols, Luvisols and Cambisols dominated (Soromessa and Kelbessa, 2013).

Vegetation

The Chilimo-Gaji Forest could be categorized in Afromontane undifferentiated forest type (Friis, 1992). Chilimo-Gaji Forest is dominated and composed of mixed broad leaved coniferous forest and characterized by the dominant tree species of *Juniperus procera*, *Podocarpus falcatus, Apodytes dimdiata, Prunus africana,* *Olea europaea* L. subsp*. cuspidata, Olinia rochetiana and Myrsine africana*. The report from Soromessa and Kelbessa (2013) indicated that Chilimo-Gaji Forest is known with its diversity and endemism with a total of 213 different plant species. Those 213 plant species were grouped into 83 families, with the highest angiosperm (91%) 193 species, followed by pteridophytes (7%) 16 species, gymnosperms (2%) 4 species (represented by 2 exotic and 2 indigenous species); including 17 plant species that are unique to the Chilimo-Gaji Forest.

Vegetation sampling procedures

Reconnaissance survey

A field reconnaissance survey of the vegetation area was executed in the Chilimo-Gaji Forest at the beginning of December 2014 to get an overview and identify various tree stands.

Sampling design

Following a reconnaissance survey, actual sampling of vegetation was done focusing on homogeneity via preferential means. In order to develop population structure, the diameter of small and big trees DBH ≥ 2.5 cm at breast and height ≥ 1.5 m were measured using diameter tape. To understand regeneration status of tree species in the study area, all tree species were recorded. Altitude, longitude and latitudes of each plot were measured using GPS. A total of 36 sampling were established. A plot of size 20 m × 20 m (400 m^2) was used for trees and shrubs, and a 5 m × 5 m (25 m^2) for seedlings. The trees and shrubs were recorded and identified following the published volumes of Flora of Ethiopia and Eritrea and authenticated specimens. The nomenclature of the plant species names were made following the published volumes of Flora of Ethiopia and Eritrea. For the purpose our study, “seedlings”, “saplings” and “mature trees/shrubs” were defined as plants with heights less than 1 m, 1 to 3 m and greater than 3 m, respectively.

Data analysis

Structural analysis

The vegetation data entry form was developed using Microsoft Excel application and subsequent analyses of the data were performed using the same application. Graphs were drawn using Excel spread sheets. All individuals of species recorded in all the 36 plots were used in the analysis of vegetation structure. Species structure (frequency, density, abundance, basal area, and importance value index (IVI) of tree species in the forest were analyzed. Importance value index (IVI) was calculated by summing up relative frequency (RF), relative density (RD) and relative dominance (RD). The DBH, basal area, tree density, frequency and important value index were used for description of vegetation structure.

Regeneration status of a given forest stand can be shown by computing the age (or size) structure of individual tree species. To describe population structure, individuals of recorded species were grouped into diameter classes at a given interval increments of DBH.

Basal area (BA)

The basal area of a tree stem is calculated from a tree diameter measurement (DBH) by assuming that the tree stem is perfectly circular with the base of the tree having same diameter as the stem at 1.5 m above ground (the height for DBH measurement). It is measured from DBH and its basal area was calculated as one of the chief characteristics to determine dominance. Therefore, relative dominance was determined as the relative value of basal area (BA) was calculated for all woody species as

$$\mathrm{BA} = \frac{\pi\ (\mathrm{DBH})^2}{4} \qquad (1)$$

Where BA = basal area in m^2; π =3.14; DBH =diameter at breast height.

Dominance

Dominance (DO) was calculated as the sum of the basal areas (BA) of the individual woody species in m^2 per ha.

Relative Dominance: Basal area of a given species divided by the sum of the basal areas of all of the species × 100

$$\text{Relative dominance (\%)} = \frac{\text{Basal Area of a species}}{\mathit{Total}\ \text{ Basal Area of all species}}\ \mathrm{X}\ 100 \qquad (2)$$

Importance Value Index (IVI)

$$\mathrm{IVI{:}\ RD + RDO + RF} \qquad (3)$$

Where RD= Relative density; RDO= Relative dominance; RF= Relative frequency.

Relative density (RD) is the number of individuals of a species divided by the total number of individuals of all species;

$$\text{Relative density (\%)} = \frac{Density\ of\ species\ \text{"A"}}{Total\ density\ of\ all\ species\ X\ 100} \qquad (4)$$

Relative frequency is the frequency of a given species expressed as a percentage of the sum of frequency values for all species present.

Regeneration status

The regeneration status of woody species was summarized based on the total count of seedlings and saplings of each species across all plots. The regeneration status of the forest was assessed using the following categories used by (Dhaulkhadi et al., 2008; Chauhan et al., 2008).

1. ‘Good regeneration, if seedling is greater than sapling and mature tree/adult (seedling density > sapling density > mature tree/adults;
2. ‘Fair’ regeneration, if seedling > or ≤ sapling ≤ mature tree;
3. ‘Poor’ regeneration, if a species survives only in the sapling stage, but has no seedlings (even though saplings may be <, >, or = mature);
4. ‘If a species is present only in an adult form, it is considered as not regenerating
5. ‘New’, if a species has no mature, but only sapling and/ or seedling stages.

For the purpose of this study seedling, saplings and mature trees/ shrubs were defined as plants with heights less than 1 m, 1-3 m and greater than 3 m respectively.

RESULTS AND DISCUSSION

Floristic composition of woody species

A total of 42 species of vascular plants belonging to 34 genera and 28 families were recorded and identified from the 36 study plots in Chilimo-Gaji Forest. The dominant 8 families of plants were Rosaceae, representing (9.76%) 4 species in four genera, Oleaceae (9.76%) 4 species in two genera, two families Flacourtiaceae and Rutaceae each of them are represented by 2 species (4.88%) in two genera, whereas the 5 families Anacardiaceae, Asteraceae, Celasteraceae, Myrisinaceae, Rhamnaceae each of them were represented by (4.88 %) 2 species in one genera respectively. The other remaining 19 families of plants were each of them represented by one genera and one species.

Frequency

This is the number of plots in which a species recorded/total number of plots. Frequency (F) was the number of sample in which the species was encountered, whereas relative frequency (RF) was computed as the ratio of the number in which a species occurred and the total occurrences of all species in all. The frequency gives an approximate indication of the homogeneity and heterogeneity of a forest stand. *O. rochetiana and J. procera* are the two most frequent species each recorded in 86.11% of the total plots sampled followed by *O. europaea* L. subsp*. cuspidata* (83.33%), *Bersama abyssinica* (72.22%), *M. africana* (69.44*%), P. falcatus* (69.44%), *Maytenus gracilipes* (66.67%), *Dovyalis abyssinica* (55.56%) and *Osyris quadripartita* (55.56%).

Regeneration status of Chilimo-Gaji Forest

Density of tree/shrub, sapling and seedlings

Density is a count of the numbers of individuals of a species within the plots (Kent and Coker, 1992). It refers to the total number of stem of a species ha $^{-1}$ which was calculated by summing up all the stems across all sample plots (abundance) and translated to hectare base for all the species encountered in the study plots whereas, relative density is a proportion of density of a species with respect to total density of all species.

Composition and density of seedlings and saplings would indicate the regeneration status of forests. The regeneration status of 42 woody species occurring in the study plots of Chilimo-Gaji Forest was analyzed, computed and used. The total density of woody plant species in all the 36 sample plots of the study area was 3328.47 individuals ha^{-1}. The total density of seedlings, saplings and trees/shurbs were 1743.7, 827.1 and 757.6 ha^{-1}, respectively as shown in (Figure 3). The top 10 densest woody species at Chilimo-Gaji Forest were (in descending order of density) *M. gracilipes* (Welw. ex Oliv.) Exell, *P. falcatus* (Thunb.) R.B. ex Mirb, *M. africana* L*., J. procera* Hochst. ex Endl*., Olea welwitschii* (Knob/.) Gilg & Schellenb*., B. abyssinica* Fresen and *O. rochetiana* A.Juss (Table). These species constituted 69.38% of all stems in all sampling plots of the study area, while the least five densest woody species at Chilimo-Gaji Forest were (in descending order of density) *Teclea nobilis* Del*., Rhamnus staddo* A.Rich., *Salix mucronata* Thunb*, Rhamnus prinoides* L'herit *and Olea capensis* L. supsp. *macrocarpa* (C. H. Wright) Verdc.

The seedling stage was represented by 35 species belonging to 28 genera and 24 families accounting only for 83.33% of the woody plant species in the forest. The densities of seedling in descending order were *M. gracilipes* (326.39 ha^{-1}), *M. africana* (234.72 ha^{-1}), *B. abyssinica* (221.53 ha^{-1}), *O. welwitschii* (175 ha^{-1}), *P. falcatus* (154.86 ha^{-1}), *D. abyssinica* (95.83 ha^{-1}) and *J. procera* (92.36 ha^{-1}) which accounted for about 74.59% of the total density of seedling (Table 1). While the sapling stage was composed of 34 species representing 29 genera and 25 families covering 80.95% of the woody plant species in the forest, the density of saplings and seedlings were dominated by few species. The sapling densities in descending order for five species were *M. africana* (117.36 ha^{-1}), *P. falcatus* (112.5 ha^{-1}), *Carissa spinarum* (79.86 ha^{-1}), *O. quadripartita* (73.61 ha^{-1}) and *J. procera* (68.06 ha^{-1}), accounting for about 54.58% of the total sapling density (Table 1).

Vegetation structure

According to Peters (1996), population structure is the numerical distribution of individuals of differing size or age within a population of a given species at a given moment of time. It can also be defined as the distribution of individuals of each species within a population in arbitrarily defined diameter height classes (Adefires, 2007). Population structure data have long been used by foresters and ecologists to investigate the regeneration profile of a species of a given population in the study plots (Woldemariam, 2003). Plant population structure may be affected due to changes in recruitment of individuals at low DBH classes or exploitation of individual at DBH or throughout the class size structure (Rocky and Mligo, 2012).

DBH distribution of Chilimo-Gaji Forest dry Afromontane Forest was classified into nine classes at an interval of 15 cm. The cumulative DBH class distribution of the woody species is given in Figure 2. In this study, the cumulative DBH class distribution showed an inverted J-shape general pattern of normal population structure which could be considered as an indication of stable population status or good regeneration status where the

Table 1. Density of tree/shrub, sapling and seedling of some select plant species in Chilimo Gaji Forest.

Botanical name	Family	Seedling	Sapling	Tree/Shrub
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	33.33	7.64	18.75
Apodytes dimdiata E. Mey. Ex Arn	Icacinaceae	6.25	3.47	5.56
Bersama abyssinica Fresen.	Melianthaceae	221.53	28.47	3.47
Calpurnia aurea (Ait.) Benth.	Fabaceae	5.56	6.25	3.47
Carissa spinarum L.	Apocynaceae	12.5	79.86	-
*Clausena anisata (*Willd.) Benth.	Rutaceae	2.08	-	-
Dovyalis abyssinica (A.Rich.) Warp.	Flacourtiaceae	95.83	14.58	2.08
Ekebergia capensis Sparrm.	Meliaceae	15.28	16.67	4.86
Erica arborea L.	Ericaceae	4.17	8.33	4.17
Gnidia glauca (Fresen.) Gilg	Thymelaeaceae	-	-	0.69
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	-	0.69	9.72
Ilex mitis (L.) Radlk.	Aquifolaceae	5.56	7.64	16.67
Jasminum abyssinicum Hochst. ex A.Rich.	Oleaceae	3.47	0	0.69
Juniperus procera Hochst. ex Endl.	Cupressaceae	92.36	68.06	168.75
Maytenus addat (Loes.) Sebsebe	Celasteraceae	41.67	12.5	6.25
Maytenus gracilipes (Welw. ex Oliv.) Exell	Celasteraceae	326.39	41.67	6.94
Maytenus obscura (A. Rich.) Cuf.	Celasteraceae	20.14	2.78	3.47
Myrica salicifolia A. Rich.	Myricaceae	3.47	1.39	5.56
Myrsine africana L.	Myrsinaceae	234.72	117.36	1.39
Myrsine melanophloeos (L.) R.Br.	Myrisinaceae	70.83	9.72	9.72
Nuxia congesta R.Br. ex Fresen.	Loganiaceae	7.64	18.06	27.08
Olea europaea L. *subsp. cuspidata (Wall. ex G.Don) c.f.*	Oleaceae	32.64	36.81	99.31
Olea capensis L. *supsp. macrocarpa (C. H. Wright) Verdc.*	Oleaceae	0.69	-	1.39
Olea welwitschii (Knob/.) Gilg & Schellenb.	Oleaceae	175	45.83	40.97
Olinia rochetiana A.Juss.	Oliniaceae	31.94	47.22	113.19
Osyris quadripartita Decn.	Santalaceae	52.08	73.61	32.64
Pittosporum viridflorum Sims	Pittosporaceae	-	1.39	2.08
Podocarpus falcatus (Thunb.) R.B. ex Mirb	Podocarpaceae	154.86	112.5	91.67
Prunus africana (Hook.f.)Kalkm.	Rosaceae	6.25	0.69	22.92
Rhamnus prinoides L'herit.	Rhamnaceae	0.69	-	-
Rhamnus staddo A.Rich.	Rhamnaceae	-	0.69	-
Rhus glutinosa subsp. glutinosa A. Rich.	Anacardiaceae	9.03	11.81	13.89
Rhus glutinosa A.Rich.subsp. neoglutinosa (M.Gilbert) M.Gilbert	Anacardiaceae	6.25	24.31	22.22
Rosa abyssinica Lindley	Rosaceae	2.08	2.78	-
Rubus apetalus Poir.	Rosaceae	-	3.47	-
Salix mucronata Thunb.	Salicaceae	-	-	0.69
Schefflera abysinica (Hochst. ex A. Rich.) Harms	Araliaceae	-	-	3.47
Scolopia theifolia Gilg	Flacourtiaceae	3.47	2.08	1.39
Sideroxylon oxyacanthum Baill.	Sapotaceae	50	15.28	12.5
Teclea nobilis Del.	Rutaceae	0.69	0.69	-
Vernonia amygdalina Del.	Asteraceae	7.64	-	-
Vernonia auriculifera Hiern.	Asteraceae	7.64	2.78	-

majority of the species had the highest number of individuals at lower DBH classes with gradual decrease towards the higher DBH classes. This implies good reproduction and recruitment potential of the vegetation (Derero et al., 2003). As the DBH class size increases, the number of individuals gradually decrease beginning from 749 stems ha^{-1} in the first class down to 38 stems ha^{-1} in the last DBH class. However, the diameter class frequency distribution of some individual species is different from the cumulative DBH class distribution. Diameter class distribution of selected tree species demonstrated various patterns of population structure,

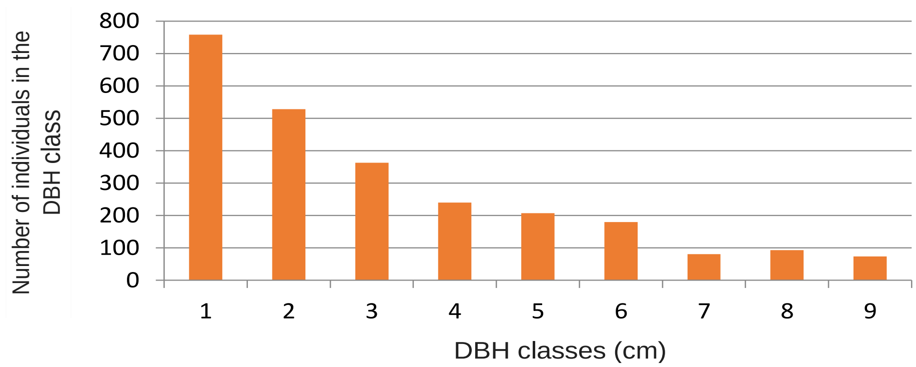

Figure 2. Cumulative frequency distribution by diameter class of woody species. DBH classes (cm): 1=<15, 2=15.1-30, 3=30.1-45, 4=45.1-60, 5=60.1-75, 6=75.1-90, 7=90.1-105, 8=105-20, 9 > 120.1.

implying different population dynamics among species (Didita et al., 2010). The slight reduction in diameter classes of some species was due to a selective removal of small diameter class individuals either by local dwellers for some purpose (e.g. for fencing and fuel wood), or by livestock (trampling or browsing), or may be other biotic factors (Wale et al., 2012), indicating selective harvesting of individuals in the particular size classes.

Basal area (BA) and important value index (IVI)

Tree species with highest dominance indices could be considered the most important species in the study vegetation. Total basal area for Chilimo-Gaji Forest dry Afromontane Forest was found to be 454.52m^2 ha^{-1}. In our study, basal area analysis across individual species revealed that very few species had high dominance. *J. procera* Hochst. ex Endl was the dominant species in the forest comprising 29.3% of the total basal area followed by *P. falcatus* (Thunb.) R.B. ex Mirb (26.23%) and *O. europaea* L. subsp. *cuspidata* (Wall. ex G.Don) c.f. (12.132%). These three woody species accounted for about 74.59% of the total basal area of the study area. This implies that these six species are the most ecologically important woody species in the study area.

Importance value index (IVI) was the summation of RDE + RFR + RDO and presented in percentage (Kent and Coker, 1992; Akwee et al., 2010). Where *R*D is relative density, *R*DO is relative dominance and *R*F is relative frequency. The importance value index compares the ecological significance of species and indicates the importance of individual tree/shrub species in the systems. It is a composite index based on the relative measures of species frequency, density and dominance (Kent and Coker, 1992). This index is used to determine the overall importance of each species in the community structure. IVI enables comparison of the ecological significance of species in a given forest type. Species with the highest importance value are dominant in the forest. The importance value index (IVI) of the most common and frequent trees of Chilimo-Gaji Forest was listed in Table 2. The importance value index (IVI) of the most common and frequent trees of Chilimo-Gaji Forest was calculated and *J. procera (*46.58) was found to have the highest IVI (Table 2). The 10 most important woody species with the highest IVIs were in decreasing order, *J. procera* Hochst. ex Endl.*, P. falcatus* (Thunb.) R.B. ex Mirb*, O. europaea* L. subsp. *cuspidata* (Wall. ex G.Don) c.f., *O. rochetiana* A.Juss., *M. gracilipes* (Welw. ex Oliv.) Exell, *M. africana* L., *B. abyssinica* Fresen, *O. welwitschii* (Knob/.) Gilg & Schellenb, *O. quadripartita* Decn and *Allophylus abyssinicus* (Hochst.) Radlk., were the top ten species in their descending order of ecological importance. These contributed over 91.11% of the total IVI (Table 2) and implies that these ten species are the most ecologically important woody species at Chilimo-Gaji Forest.

Regeneration status of woody species in Chilimo-Gaji Forest

The density values of seedling and saplings are considered as regeneration potential of the species (Robi, 2016). The successful regeneration of a given forest requires the occurrence of a sufficient number of young trees, saplings and seedlings in population (Hanief et al., 2016).

The total density of mature tree/shrub, sapling and seedling of the study plots was 757.64 (23%), 827.08 (25%) and 1743.75 (52%) individuals ha^{-1} respectively (Figure 3). Density ha^{-1} of the species showed that seedling > sapling > matured tree in Chilimo-Gaji Forest natural forest. Based on the criteria of Tiwari et al. (2010), indicating the species is categorized under the species with good regeneration. The calculation of the ratio among the seedling, sapling and mature tree can provide information regarding the distribution of mature tree, sapling, seedling and the regeneration status of the

Table 2. Importance value indices for woody species in Chilimo-Gaji Forest.

Botanical Name	Relative Density	Relative Frequency	Relative dominance	IVI	Rank
Allophylus abyssinicus (Hochst.) Radlk.	1.77	4.34	2.48	8.58	10
Apodytes dimdiata E. Mey ex Arn.	0.45	1.45	0.81	2.71	23
Bersama abyssinica Fresen.	7.49	6.27	0.37	14.13	7
Calpurnia aurea (Ait.) Benth.	0.45	3.13	0.14	3.73	20
Carissa spinarum L.	2.73	2.17	0.23	5.13	16
Clausena anisata (Willd.)Benth.	0.06	0.48	0.00	0.55	34
Dovyalis abyssinica (A.Rich.) Warp.	3.33	4.82	0.26	8.40	11
Ekebergia capensis Sparrm.	1.09	2.65	0.85	4.59	17
Erica arborea L.	0.49	1.45	0.16	2.10	26
Gnidia glauca (Fresen.) Gilg	0.02	0.24	0.03	0.29	40
Hagenia abyssinica (Bruce) J.F. Gmel.	0.31	1.20	0.86	2.37	24
Ilex mitis (L.) Radlk.	0.88	1.20	1.42	3.50	21
Jasminum abyssinicum Hochst. ex A.Rich.	0.12	0.48	0.00	0.61	31
Juniperus procera Hochst. ex Endl.	9.73	7.47	29.30	46.50	1
Maytenus addat (Loes.) Sebsebe	3.45	1.45	0.09	4.98	19
Maytenus gracilipes (Welw. ex Oliv.) Exell	10.88	5.78	1.51	18.18	5
Maytenus obscura (A. Rich.) Cuf.	0.78	1.93	0.17	2.88	22
Myrica salicifolia A. Rich.	0.31	0.24	0.20	0.74	30
Myrsine africana L.	10.45	6.02	1.02	17.49	6
Myrsine melanophloeos (L.) R.Br.	2.69	1.45	0.47	4.60	17
Nuxia congesta R.Br. ex Fresen.	1.56	3.61	1.96	7.14	12
Olea europaea L. *subsp. cuspidata (Wall. ex G.Don) c.f.*	4.99	7.23	12.13	24.35	3
Olea capensis L. *supsp. macrocarpa (C. H. Wright) Verdc.*	0.06	0.48	0.03	0.57	33
Olea welwitschii (Knob/.) Gilg & Schellenb.	7.74	3.13	2.82	13.69	8
Olinia rochetiana A.Juss.	5.69	7.47	7.74	20.90	4
Osyris quadripartita Decn.	4.68	4.82	1.68	11.18	9
Pittosporum viridflorum Sims	0.10	0.48	0.00	0.59	32
Podocarpus falcatus (Thunb.) R.B. ex Mirb	10.62	6.02	26.23	42.87	2
Prunus africana (Hook.f.)Kalkm.	0.84	2.17	3.67	6.68	13
Rhamnus prinoides L'herit.	0.02	0.24	0.00	0.26	42
Rhamnus staddo A.Rich.	0.02	0.24	0.00	0.26	41
Rhus glutinosa subsp. glutinosa A. Rich.	1.05	0.96	0.22	2.23	25
Rhus glutinosa A.Rich.subsp. neoglutinosa (M.Gilbert) M.Gilbert	1.56	2.89	1.40	5.85	15
Rosa abyssinica Lindley	0.14	0.24	0.00	0.39	37
Rubus apetalus Poir.	0.10	0.24	0.00	0.34	38
Salix mucronata Thunb.	0.02	0.24	0.07	0.33	39
Schefflera abysinica (Hochst. ex A. Rich.) Harms	0.10	0.72	0.30	1.12	27
Scolopia theifolia Gilg	0.21	0.48	0.15	0.84	28
Sideroxylon oxyacanthum Baill.	2.30	3.13	1.18	6.61	14
Teclea nobilis Del.	0.04	0.48	0.03	0.55	34
Vernonia amygdalina Del.	0.35	0.24	0.01	0.60	36
Vernonia auriculifera Hiern.	0.31	0.48	0.02	0.81	29
Total	**100**	**100**	**100**	**300**	

species (Chauhan et al., 2008; Robi, 2016). In line with this, the ration of seedling to sapling, seedling to mature tree and sapling to mature tree of the species was conducted and the result was 2.11:0.47, 2.30:0.43 and 1.09:0.92, respectively. These reveal that the distribution of seedling density is greater than both sapling and mature tree/shrub. The successful regeneration of a given forest requires the occurrence of a sufficient number of young trees, saplings and seedlings in population (Hanief et al., 2016). Hence, in this study

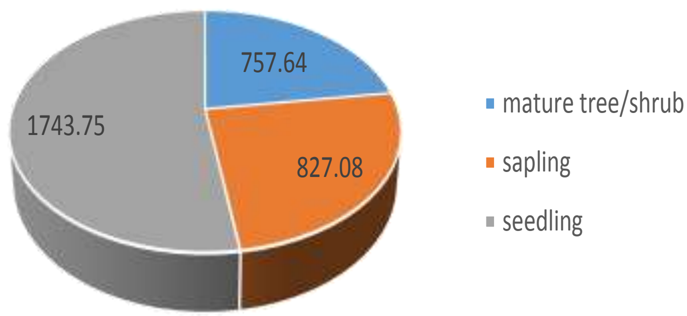

Figure 3. Density of seedling, sapling and mature tree/shrubs.

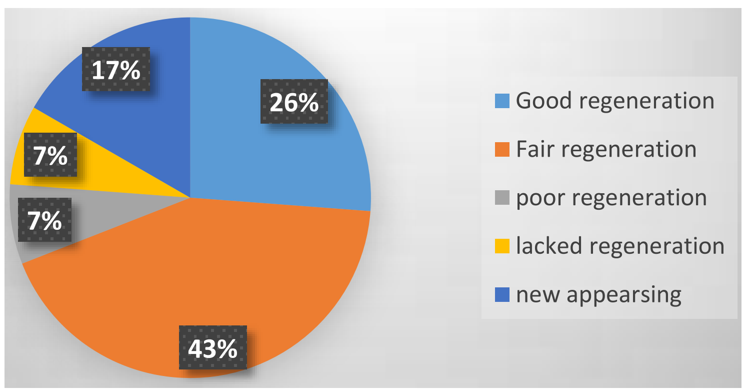

Figure 4. Regenration status of individuals based on Dhaulkhadi et al. (2008) and Chauhan et al. (2008) categories.

there is sufficient amount of seedling and sapling is availabile as a potential for regeneration and recruitment (Figure 3).

As far as the regeneration status of each species is concerned and based on the categories used by Dhaulkhadi et al. (2008) and Chauhan et al. (2008); out of the 42 wood species, eleven (26.19%) tree species achieved good regeneration, eighten (42.86%) species had fair regeneration, three (7.14%) had poor regeneration, three (7.4%) lacked regeneration, and seven (16.66%) were appearing as new species regenerating (Figure 4).

Most of the species in the current study had shown differences in forest structure. In this study, the diameter class frequency distribution of selected species with high IVI had four different patterns. The first pattern of structure is reverse J-shape which is characteristic for many tropical forests (Richards, 1996) exemplified by *P. africana* and *P. falcatus* (Figure 5), with a successful regeneration (Poorter et al., 1996). This pattern indicates the presence of highest density in the lower DBH classes with gradual decrease in density towards the bigger classes, which suggests good reproduction and recruitment (Derero et al., 2003; Lulekal et al., 2008) (Figure 5). The second pattern is interrupted inverted J curve population. This pattern shows high frequency in the lower DBH classes followed by a gradual decrease and absence of representative individuals after the middle class. It suggests good reproduction but bad recruitment exemplified by *M. Africana* and *B. abyssinica* (Figure 5). The third pattern is the irregularly interrupted DBH distributions that indicate poor regeneration and recruitment exemplified by *Ekebergia capensis* (Figure 5), while the Fourth is depicted as Bell-shaped pattern which reflects discontinuous or irregular recruitment in which regeneration has been inhibited by vigorous growth of young cohort populations of the dominant canopy tree (Måren and Vetaas, 2007).

Conclusion

In this study, floristic composition vegetation structure and regeneration patterns were determined for the woodland vegetation in Chilimo-Gaji Forest. Rosaceae was found to be the most dominant family followed by

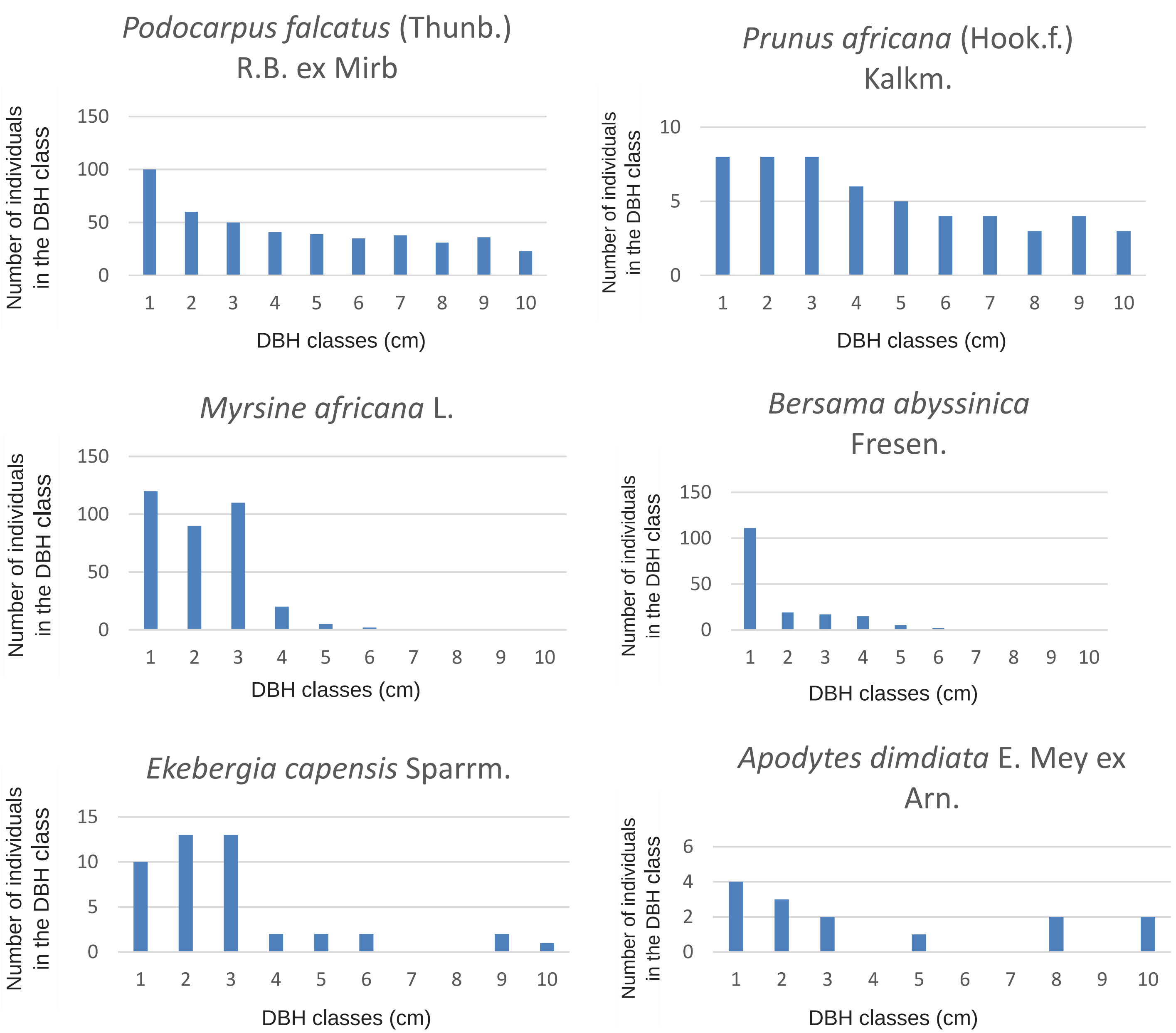

Figure 5. The four population structure of selected tree species classified according to different DBH (cm) classes, such as, 1 =<10, 2 = 10.1–25.0, 3 = 25.1–40.0, 4 = 40.1–55.0, 5 = 55.1–70.0, 6 = 70.1–85.0, 7 = 85.1–100.0, 8 = 100.1–115.0, 9 = 115.1–130.0, 10 > 130.1.

Oleaceae, Flacourtiaceae and Rutaceae. The results of this study is important in understanding the patterns of the vegetation structure and regeneration status of wood species in Chilimo-Gaji Forest, which is generously significant for the sustainable utilization, management and decision making for the future conservation of the forest. Abundance of seedlings and saplings are indicators of the establishment of young individuals. In this study, generally, the regeneration of wood species has shown that contribution of seedlings density was highest followed by saplings and adult trees, representing relatively a healthy regeneration of the species. This implies that the overall regeneration status of wood species in the study area has good reproduction and recruitment potential of the vegetation though dominated by few species.

The presence of good reproduction and recruitment for regeneration of species is an important effective strategy for restoration of the tropical secondary forest, which further helps to sustain the future natural forest ecosystem. However, woody species represented by “poor” or “no” regeneration of growth, survival, and reproduction potential at risk in future, needs systematic management plan for their conservation and sustainable utilization (Singh et al., 2016) and should be given priority in conservation, for example, *Pittosporum viridflorum, Jasminum abyssinicum, Rhamnus staddo, Gnidia glauca, Rubus apetalus, Salix mucronata,* and *Schefflera abysinica*. The forest management paradigm in Ethiopia has recently shifted from conventional management approach to community based forest management under protected area management scheme. As the result of the implementation of participatory forest management since 1996, in the current study area, has contributed for the successful regeneration of some wood species specifically the indigenous trees such as *P. falcatus, M. africana, B. abyssinica and J. procera,* indicating scaling up of the participatory forest management to other forests under restricted management to promote sustainable utilization and management of the forest resources.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Governance of river basin: Gender dimension in framing issues at the local community level

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Rivers are a vital part of the environment as they act as habitat for several life forms, of which the well-being of many livelihoods depends for survival. Yet, the misuse of river basins in most parts of the world particularly developing countries has intensified dramatically. Appling the concept of "framing" we attempted to understand how gendered perspectives play a role in the governance of a river basin at a community level. We **conducted 25 in-depth interviews over a three month period (April to June, 2017) with participants from five communities within the Tano River catchment area in Ghana. The study revealed that river-related issues at the community level continue to be framed based on some predetermined notions that have been traditionally ascribed to men and women. It was observed that the existing frames, in theory, determined whose voice is included or excluded from a decision making processes. However, the participant's framing of roles did not reflect the specific roles women must undertake in the decision making processes at the community level. Women's opinions are considered a second option at the local decision making level. A grey area to a social dimension in water governance indicates that women as traditionally required, delegate their opinions to men to deliver on decision platforms, and therefore it will be difficult to ensure gender equality in the management of river basins at the community level. Thus, the framing of issues at the community level plays a pivotal role in determining who participates or not in a decision making process.**

Key words: Framing concept, gender roles, water governance, taboos, decision making, the Tano River basin.

INTRODUCTION

Water-related issues are one of the key challenges facing humanity in the 21st Century (Peterson and Feldpausch-Parker, 2013). The Scarcity of supply, inequities in access, allocation, and use of water among various users with varied priorities have increasingly led to conflict over water at different scales (Gehrig and Rogers, 2009). At the local community level, preventing and mitigating water-related issues necessitates context-specific governance approach to water management (Gehrig and Rogers 2009; Yerian et al., 2014). Research suggests that, when participants' interests compete over rights of the same consensus value, they spend a good deal of

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effort framing the values (ideals) as well as the issues (problems) (Patrick et al., 2014; Tracylee and Peterson, 2016).

Framing theorists hold the assumption that the issues and the potential significance must be brought into conformity with each other's interest in a conflict situation. However, the applicability of the frames and its importance are often not understandable to all those involved. Furthermore the cultural environments (e.g. traditional beliefs) in some traditional communities tend to favor men's voices over that of women and may exclude the views of the latter particularly in river related issues (World Bank, 2016). Yet, women are known to play a significant role in the management of water resources. Their traditional roles include the handling and collection of water for domestic use and agriculture (Howard and Bartram, 2003; Ray, 2007). African women traditionally have had a close affiliation with rivers and research suggests the need to include their frames in the management of water resources (Ray, 2007).

In Ghana, there are generalized issues over water supply, access, distribution, allocation and utilization of water among users. The related issues include siltation, contamination from mining and farming activities, drying up of rivers and scarcity of safe drinking water. The numbers and intensity of such water-related issues are projected to increase in the near future particularly in areas being affected by scarcity, long droughts and climate variability (Ravnborg, 2004; Wolf et al., 2005). Managing and mitigating local level water-related conflicts demands the adoption of a context-specific governance approach to address the divergent needs and concerns of local communities (Ravnborg, 2004; Wolf et al., 2005; Gehrig and Rogers, 2009). Some authors have modified the framing theory to understand different societal conditions. For example, *Dewulf et al.,* (2011) analyzed the fragmentation and connection of frames in collaborative water governance projects in the Paute catchment and its sub-catchment Tabacay in the Southern Andes of Ecuador.

Patrick et al. (2014) used a case study from the Murray-Darling Basin in Australia to illustrate how reframing a water management issue across multiple scales and levels could help understanding stakeholders' perceptions of justice and injustice. Additionally, Buijs et al. (2011) introduced the social representations theory as a way to understand the cultural resonance of spatial and environmental frames in the environmental conflict in the Netherlands. McLeod and Detenber (1999) included gender in their study on frame effects, nevertheless without discussing the importance of this variable. Despite the fact that several authors have contributed to the understanding of the origin of distinct social conflicts, none of them take in consideration the gender variability. Considering that the gender dimension is of extreme importance in originating variability in the social context, the present study sought to address the importance of such a variable into the "framing theory", by studying the social issues and conflicts generated by the water scarcity in the Tano River basin, Ghana.

It is argued that with the current rate of degradation, it is reasoned that the current government approach has been insufficient in addressing the challenges facing the Tano river basin. Hence, the study was set to gain a better understanding of how participants frame issues in relation to the management of the Tano River basin whiles advancing at theoretical knowledge and uncovering of the critical areas in the governance processes of a river basin at a local level. Central to this research was "How gendered perspectives influenced resource users' notions of river related issues at the community level"? Specifically, we addressed the following questions;

1. How are the river-related issues framed at the local community level?
2. What factors influence the framing of issues by women and men at the local community level?
3. What roles do women and men play in the decision making processes in relation to the management of the river basin?

METHODOLOGY

This study employed a qualitative case study approach to explore the issues relating to the Tano River Basin. Case studies are not always useful in assessing community issues but they can be very effective in convincing policymakers of the importance of those issues and action needing (Berg, 2007). A case study is defined as "empirical enquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used", its goal is to provide a clear understanding of the issues rather than generalized findings (Yin, 2009).

Study area

The area selected for performing the study was the Tano River Basin as a case to understand how participants frame issues relating to the river. The Tano River was selected for the following reasons:

1. Major water supply for millions of people and many communities,
2. A major source of livelihoods for local communities along the river,
3. Increasing environmental concerns because of anthropogenic activities along the river and its basin,
4. Fringe Communities' roles in the management of the river and its basin.

The Tano River Basin is located in the southwestern part of Ghana and lies between latitudes 50′N and 70°40′ N and longitudes 20°00′ W and 30°15′ N (WRC, 2012). The landscape of the Tano River Basin ranges between 0 and 700 m above sea level (WRC Ghana, 2015). The climate conditions in the area also fall partly under wet, semi-equatorial and partly under the south-western equatorial climatic zone of Ghana. The basin experiences double rainfall maxima (USAID, 2011). The Tano River is transboundary and the last 100 km downstream reaches the international boundary

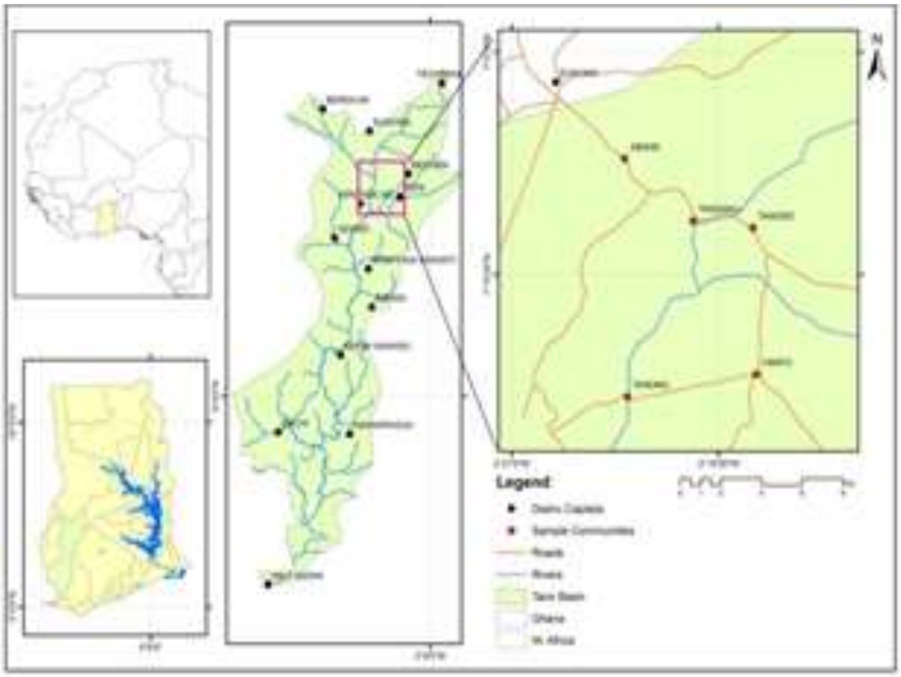

Figure 1. Location map of the area (shown in pink square) and selected communities (shown in red stars).

between Ghana and Côte d'Ivoire where it flows into the Aby-Tendo-Ehy lagoon system. The total catchment area of the Tano Basin (14,852 km^2) according to the WRC (2015) is split between Ghana (93%) and Côte d'Ivoire (7%). The Tano Basin spans about 35% of the land area of Brong Ahafo region.

The Tano River basin in Ghana provides water to serve the Sunyani city and its surrounding communities. Activities of the local communities along the river basin pose serious threats limiting its potential to meet the diverse needs of the inhabitants. These activities include intensive agriculture along and within the river buffer areas, intensive use of agrochemicals and clay extraction for pottery production, deforestation, bushfires, and alluvial mining or "galamsay" (personal communication with a paramount chief, 2016). Also, the river is shrinking in width and depth as a result of siltation and settlements extension.

The diverse activities have contributed to the pollution of the water, making water treatment highly costly for the Ghana Water Company limited according to GWCL personnel (2016), posing a serious health risk to the local communities that directly use water from the river. The health sector in Ghana frequently receive reports of diseases such as typhoid fever, cholera (diarrhea), and other water borne diseases occurring amongst the inhabitants of some of the local communities (UN-GLASS Report, 2014; WHO, 2014).

Data collection

Five local communities were selected for the interviews: Abesim, Tanoso, Tano Ano, Tanomu and Yamfo communities (Figure 1). The communities were selected based on their proximity and related activities of the inhabitants within the catchment areas. The Purposive sampling method was used and a total of 25 participants (five from each community) was recruited and interviewed. The study adopted a conversation-style interview approach. The interviews were conducted in the local dialect and with an informed consent (Byrne, 2001) of the participant recorded and transcribed to facilitate data analysis.

Explaining the purpose of the study to participants before each interview was a key concern during the field work. The interviews aimed at eliciting participants views on the issues of management, decision making processes and general participation of community members in the protection of the Tano River basin. Participants were purposively sampled to include local leaders/chiefs, opinion leaders, key decision makers and farmers conducting most of their activities within the catchment area.

These categories of participants were considered by the researcher as those who could provide the needed data to achieve the purpose of the study. Secondly, they were considered as those knowledgeable about the area under study. Among the 25 participants, three (3) were women aged between 26 to 45 years and the remaining 22 were men. The male participants were aged between 25 to 65 years. In addition to the field interviews with participants, the researcher also carried out observations of the activities occurring within the catchment areas. This was meant to develop firsthand knowledge of some of the concerns and issues mentioned by the participants during interviews. The category and numerical distribution of research participants have been provided in Table 1.

For data analysis, a logical approach was adopted to evaluate and identify the existing patterns in the governance processes at the community level. The audio recordings of the interviews were translated and transcribed from the local dialect (that is, Twi) into English and stored as word files on a computer for the analysis to be done. Field notes included visual observations and photos of some of the human activities along the Tano River basin. The transcribed interviews were analyzed by getting familiarized with the content and identifying codes and ordering them into a list of recurring themes under which the data was to be tagged and sorted. Once these recurring themes were noted, a conceptual framework was devised based both upon the recurrent themes and

Table 1. Distribution of participants by communities.

variables	Tanoso	Abesim	Tanoano	Yamfo	Tanomu	Total
Farmers	2	3	2	3	3	14
Traditional Head	1	*	1	*	1	3
Assembly Man	1	1	*	1	*	3
Unit Community member	1	1	2	1	1	5
Total	5	5	5	5	5	25

Source: Authors own construct 2016.
* denotes category with no participant interviewed in a particular community.

answers to questions introduced to the interviewees.

Multiple sources of information in the process of achieving inquiry credibility were used (Bailey, 2007; Yin, 2009). Existing documents/ reports, in-depth interviews and observation of activities within the river were relied on to understand how frames evolved among the participants. During the data collection, some participants were revisited for the purposes of getting a better understanding of issues that were not clear after playing back to the audio recordings. This was to ensure internal validity. For the purposes of external validity, the researcher tried to include as many participants as possible. Furthermore, in the process of ensuring credibility, appropriate representation of views of the phenomenon under study was done. According to Corden and Sainsbury, (2007) and White et al., (2003), the use of quotations to represent the views of research participants in a qualitative study helps to establish credibility. Therefore, relevant quotations to represent and justify the themes were identified. For reliability, a strategy that could easily be reproduced to obtain similar outcomes when the study should be repeated in the area was adopted.

RESULTS

Some of the themes that emerged were traditional beliefs, taboos, women participation and gender roles. The main issues that came up from the participants during the fieldwork relied on:

1. Usage of the river and its basin by the inhabitants,
2. Degradation and siltation of the river,
3. Pollution of the river.

These issues were mainly related to the following themes: access or usage, protection and management of the Tano River basin. Participants framed the issues affecting the Tano River basin on the basis of institutional/policy failures, lack of respect for authority, and failure of traditional governance systems. The study revealed that at the local community level, there were laid down procedures for accessing and using the Tano River basin based on some traditional belief systems. For example, one of the participants explained that; "In the past, lands bordering the river about 20 to 50 yards wide belonged to the chief and no one was allowed to do anything within that area and violators were punished. But now people do whatever they like and go unpunished because they think they have a right".

Another noticeable issue mentioned by the participants was on the pollution and siltation of the Tano River.

According to the participants, the illegal mining of alluvial gold in and around the catchment areas was affecting the flow and colour of the river hence affecting the usability of the water from the river. This issue was framed as an institutional or policy problem than one that can be solved mainly at the community or local level. Participants were of the view that, the problem required a political will and commitment to get solved. The participants framed the issue of small scale mining in the area as one that is being caused by politicians who they claim are the owners of the equipment being used. For example, a participant illustrated this by saying that;

"My brother, the machines they are using are expensive and those operating the small mines cannot afford them. They are owned by the big men (politicians) so even when you arrest them, they get bailed and go back to do it again. How can we here in the village stop such powerful people"?

This issue was mentioned by almost all the participants and they explained this by saying that;

"The main challenge of the communities was the activities of the illicit miners or "galamsay" operator around the area. When the issue of galamsey started in this area, the traditional leaders and opinion leader from the communities called on the Environmental Protection Agency (EPA), the Regional Police Command, BNI and the Military to intervene. But we realized that even if we made arrests, the perpetrators were released without being prosecuted or even fined".

From what the participants reported, it seems that the policy might not have been effective in regulating small-l scale mining activities, hence the challenges being faced by the fringe communities in the area. Some of the participants also framed the problems of degradation along the river based on lack of respect for traditional or local authority by the community members. They were of the view that, the young men in the communities no longer had respect for the local rules. This they blamed on the fact that some of the local authorities themselves were behind the illegal mining activities indicative of an "invisible hand" hence difficulty in curbing the problem. This revelation from the study was also an indication that governance issues at all level of society do not occur in isolation.

When asked to indicate the institution that was responsible for the management of the river basin, none of the participants mentioned the Water Resources Commission. This revelation was indicative of the fact that the authorities at the national and regional levels responsible to facilitate the policy on the management of the Tano River Basin seem to have failed in their work. Again when the participants were asked about the mining or collection of clay within the catchment area which was found to be a booming business in the area, participants again framed the issues differently. Some of the participants were of the view that the activity was affecting the river whereas some were of the view that is had no effect on the river. For example, one participant explained that;

"When they collect the clay from the area, they leave behind gullies which make working on our farms dangerous since one can fall into it. Also when it rains heavily, water collects in the gullies attracting dangerous reptiles to the areas".

On the other hand, other participants were of the opinion that collection of clay caused no problems but rather was beneficial to the catchment. In an attempt to explain this, one participant mentioned that;

"The activity of clay collectors does not affect the river in any way. Collection of clay does not have any effect on the river. You see, if you mine clay from one area and leave to another area, the area you first mined refills naturally. This is because the areas with the clay melt to cover up the opening especially during the raining season. So the when you go back to the old sites where clay was collected, you find that the gullies have been naturally refilled. Even the clay is collected far from the river bank and not very close to the river so it does not affect the River in any way".

Finally, river-related issues were framed based on the failure of traditional systems. According to the participants, the coming of Christianity has led to a total disregard for traditional norms. The traditional authorities themselves no longer perform rituals to appease the gods and some participants think that the gods were punishing the communities. For example, some of the participants explained that;

"We the inhabitants of the communities fringing the Tano River are not allowed to rear goats in our community. But these days there are some communities keeping goats which are against the traditional rules yet the leaders are not taking any action".

It was revealed by the interviews that there were institutional challenges at the community level where there seem to exist a break up in the local protocols that are used to govern environmental resources. It can be argued that there is lack of coordination in institutional arrangements among the responsible sectors and the communities thereby having a negative effect on the implementation of the integrated water management approach being implemented to achieve the sustainable development agenda. The interviews further revealed some key sets of themes under which participants framed river-related issues at the community level from a gendered perspective. This study revealed that gender played a key role in the framing of river related issues by participants at the community level. Whereas women were framed as emotionally concerned individuals and good decision makers (idealistic) and they were also framed as physically weak, not strong and not good enough or "adulterated" (that is, when in their menses). To illustrate this, a unit committee member said that:

"Women are those who are more concerned about the availability of water for household use whiles men will probably be looking at their farming, irrigation and other industrial uses of water. Whiles women are thinking about household uses, men are looking at agricultural usage. When it comes to taking good care of water resources, women are always very concerned and actively involved in water related issues than the men. Women use the water for cooking, washing and bathing their children and the men use the water to grow their crops".

Framing women as those who are more concerned about rivers and the related issues are correspondence with what Brody (2009) describes as the placing of women in "soft policy" areas. Such framing of gender roles "women" continues to keep them in a marginalized position in the broader sense. Thus, the roles women are expected to play are often shrouded by the roles they are expected to play at the household or community level which often exclude them from participating in decision making processes (Baden, 2000). Research participants also framed themselves (men) differently from the women in relation to the decision making processes at the local level. Men generally framed women as good decision makers but also framed them as weak (not strong physically) for example to arrest offenders or chasing and driving away wrongdoers. A participant explained that:

"In this community, we all have an equal say. I can admit that women are generally good at coming up with ideas, but I will tell you that the women usually stay away and allow only the men to take the action. As for me this is not good. We all have to take part so that no one feels left out. We have farmers who are men and some women so I don't see why the women will not take part. Everybody's

idea is important, be it from a man or woman and so is our participation in solving the problems. The problem is that the women are not strong enough to do certain things like arresting the "galamsey" miners. It is we the men who can do that so in such a case we have to do things the men way. We cannot bring in the women".

Using physical abilities, women were framed by their men counterparts as not physically capable (strong or robust) to take part in certain river management events. A vegetable farmer and a unit committee member exemplify this by saying that:

"The cutting down of trees along the river is being done by the inhabitants (young men) of this community. You cannot blame it on anyone. Women do not engage in the logging activities because they are not strong enough to carry the logs. It is the young men who engage in it.

Participants also based their framing of river-related issues based on the kind of uses and outcomes that could result when resources are used by both women and men. Men were framed by the participants as destructive and poor management agents in terms of resource exploitation. For instance, the participant mentioned that;

"Activities of men causes more problems to the river than those of women because men are mostly involved in the mining activities and cutting down of trees along the river. Therefore we cannot leave the decision making solely in the men's hands. They may end up destroying everything I tell you".

Similarly, one of the participants, a farmer who has taken part in a couple of community meetings to discuss how the Tano River basin should be managed and protected at the community level in his explanation mentioned that:

"We involve women because basically most of the pollution activities that affect the river come from activities of men and not the women. The women mainly use water for household activities so they are more concerned about the water they are using".

Meanwhile one of the participants buttressed the idea of women being physically not strong to take certain decisions yet repositories of good ideas by saying that:

"The women are very important and we have to give them the chance to also contribute. The only problem is when it comes to taking "action" then they have to be left out. The action I mean when we are to do things that demand physical strength, women I will say are handicapped. For example if we are to go and arrest the "galamsey" miners, the women cannot go because of fear of getting injured. The women are also sometimes afraid of reporting wrongdoings when they see them of fear that they may be attacked or even get beaten by the men".

Factors influencing the framing of issues by women and men

There are several factors that contribute to framing among a group of people. The main factors that were mentioned by the participants are: Tradition, customs and taboos; socio-economic factors; and weakening traditional laws.

Traditions, customs, and taboos

Taboos are basically traditional beliefs that vehemently prohibit members of a local community from taking part in certain activities at one point in time (Crossman, 2017). Such taboos were said to have deep rooted histories behind them. The rationale behind some of these traditional laws as mentioned by the participants was to regulate the conduct of the inhabitants who lived and conducted their livelihood activities around the Tano River. An opinion leader in one of the communities pointed out some of the taboos and superstitions that surrounded the Tano River basin by saying that:

"The Tano River takes its source from a small Town close to Tachiman called Tuobodom and flows through several communities including Tanoso. The Tano River since my childhood has never run dry not even in the period of a long drought. Traditionally, the River is believed to be a human being (White Woman) and have a lot of power. She (the River) sometimes visits the community through the chief priest to announce a wrong that has been done to her and rites were performed to appease her. In the olden days, the Tano River was known for ***her*** *ability to overflow its banks (flood) even in the severe dry seasons when there are no rains.*

Some of the taboos that were observed in the interviewed communities were:

1. Nobody (man or woman) is allowed to use a black cooking pot to fetch water directly from the River.
2. Nobody goes to work on his or her farm close to the river on all Mondays in a week.
3. Nobody (man or woman) was allowed to farm or weed directly to the River's bank.
4. Nobody in any of the fringe communities is allowed to keep livestock (notably goats) for any purpose.
5. A woman in her menses was not allowed to visit the River to fetch water
6. Nobody (man or woman) is allowed to fish or eat any fish harvested from the Tano River.

7. She (the River) and her children come out on Mondays so nobody goes to farm on Monday to work.
8. We don't bath with soap in the River and we do not wash directly in the River Tano.

These taboos, according to some of the participants, were very effective in protecting the River in the past but were gradually losing their values due to the reasons as the inclusion of churches (*Christian faith)*, increased knowledge and technological advancement, deviancy and open disregard for traditional authority/values on the part of some individuals. Two participants (village elders) who have lived in their respective communities since they were born pointed out that the traditional values and authority were being lost among the citizenry. They revealed in their explanations that:

"*Currently people have advanced in knowledge, and they think they have a right and no one can tamper with their rights, so they do whatever they like disregarding our old customs. Because of that, people (farmers) now weed very close and even directly into the river exposing it to direct sunshine. You know something our ancestors were really wise people. In the past, lands bordering the river about 20 to 50 yards wide belonged to the chief and no one was allowed to do anything within that area and violators were punished. Even when someone taps wine (locally called nsafufuo or doka) from a palm tree within that area, they brought the wine to the chief's palace. Traditionally, it meant that any resources within that demarcated (20 to 50 yards) area belonged to the chief and once something belongs to the chief, no one can go near it and this was a traditional strategy meant to protect the River. During these periods when people were adhering to these local customs, the Tano River used to flow under trees (forest areas) and it was clean for drinking and used for many other purposes".*

Social and economic factors

Men as the household heads are traditionally expected to provide for their families and therefore use all means possible to meet the demands of their families. Women according to the participants are there to cater for the family taking care of the domestic activities like fetching water, cooking and necessarily do not do things that will affect the River. For example a vegetable farmer with a family of three kids and a wife mentions that:

"Women only use water from the River for household activities and we the men use it for our farming needs. The people who engage in farming along the river (vegetable farmers) and mining of clay are mostly men. This is because of vegetable farming and clay mining activities are labor intensive and stressful and very few women can do it. But this does not mean that men do not want to protect the River. We the men are also using the resources along and within the River as a means to make an income to cater for our families".

Dwindling prominence of traditional authority

A number of the participants pointed out that the Traditional Authorities were losing control of their authority. For example, a youth leader said that:

"The chiefs in our communities should sit-up and perform their duties. The chiefs (Ahenfo) and their elders no longer perform rituals to the River goddess and the deities (nananom) as traditionally required. These days, they only do so when there is a severe calamity in a community, for example when someone gets drowned in the River. You will be surprised that nowadays, women of all ages go swimming in the River and nobody restricts or says anything to them. At first young ladies in their pubertal age were not allowed to swim in the River except for kids. But now you see all manner of persons in the river when it is full. The chiefs and elders are sitting and watching the youth to trample on the local customs all in the name of people saying they know their right".

Women as a second option in decision making

One of the main challenges to gender participation as revealed by the study participants was that men as well as some of the women themselves continue to see "women" as second to men particularly when it comes to decision making.

Hence much of the decisions are taken by the men without much involvement of the women. A clay product manufacturing businessman in his perspective exemplified this by mentioning that:

"I am not against the idea that women should be involved in decision making. But you have to know that I am the man of the house and some decisions I have to take them alone. Sometimes I want things to be done very fast but my wife may come up with ideas that will delay me so I don't always get her involved in all my decisions".

A trader and one of the three women who participated in the study mentioned that:

"Men can be stubborn at times and you know it. It is not like we (women) do not want to participate or contribute our minds when it comes to decision making. But the fact is that they are the men and the head of the house and they can do what they like. For example my husband can decide to take my suggestions on an issue but still do what he thinks is good and I cannot really say anything".

The political connotation of issues and lack of confidence in authorities

It is common to find that political meanings are given to issues particularly when it is about decision making and representation. The interviews revealed that participants, across their respective communities, seem to be losing trust and confidence in the acclaimed representative decision making procedures both at the local and national levels. A male farmer in his interpretation said that:

“Even when we go there to say our minds, they still do what they want. They only try to create the impression that they are involving us. If you say something that is in contrast to someone’s view at such gatherings, they will only paint you with a political colour. Therefore, I don’t see the need for me to be there or to say anything that will not even be taken. They (in reference to local leaders) should do what they like”.

The overburden of women with domestic responsibilities

Traditionally women in local communities are overly burdened with house activities such as bathing their children, cooking, fetching water or making provisions for their husbands and often have less time to engage in other activities. Another female participant who is a farmer and married with two children in her submission mentioned that:

“I am a unit committee member but I usually have too much work to do in the house and I don’t have the time to attend such meetings. In this community, they usually call for such meetings on market days. They know everybody will be around to attend because we do not go to our farms on market days. But such days (time) are not convenient for some of us because a married woman with kids I have to go to the market to shop for items that we may need during the week. So my husband can attend the meeting and bring me the feedback. Even if I happen to attend, I do not speak. I sometimes attend because I am a member of the unit committee but I only do so if I don’t have much to do at home”.

Gender roles in decision making on issues related to the river at the local community level

Roles of women and men in decision making processes were not clearly indicated by the participants. For example, a cocoa farmer said:

“The participation of men and women in my opinion is very important. We are all part of the community and anything that goes wrong in the community affects us all even if not equally. Therefore taking a decision as a community is not really about men or women. Anyone who is willing to get involved is allowed to participate in the process”.

The interviews revealed that at the local community level, decisions mainly took place at the chief’s palace. The rationale behind this is that the Chief, as the head of the community, uses the palace to serve as a local court for decision making and adjudication of matters; however, there are some limitations as who is allowed to speak and who is not. The participants indicated that the decision making processes were traditionally laid out and everybody could participate in being guided by the traditional customs. An assemblyman explained that:

“We do not discriminate between men and women we only follow our traditions when making a decision. You know that traditionally there are some things or areas that women are not allowed to do or go close to in a certain time. Even this is changing because we all know the government is saying we should give equal opportunities for men and women to making decisions and so we now have women in parliament. So at the traditional level we also allow women to voice their views just that we still try to keep our traditional ways of doing things. It is not every gathering that women can actually participate in or talk”.

Conditions necessary to enhance gendered perspectives in river basin management

General views on possible measures or conditions to ensure gender participation as mentioned by the research participants were as follows: Education or awareness creation, the formation of women groups, and empowerment of women to take leadership positions.

Education and awareness creation

Creating awareness especially amongst women at the community level; thus educating them on the need for participation in decision making was much articulated by the participants. The rationale as mentioned by the participants was that customs have changed and women need to understand that they are part of the society and anything that happens in it also affects them. A male participant explains this by saying that:

“Women need to be informed that they are also important to the process of developing this community. The media people should try to say this on their radio stations for women and all other people to know that we have to come together to protect our resources. I think that a lot of people still do not know this and we all have to help in passing on this understanding within our community. I

think that educated people like you can go round communities to give out this message to the people for better understanding".

Formation of an all-women decision making group

Formation of women associations is thought of as a mechanism that will empower women. According to the participants, women will take up leadership positions and by so they will have the courage to speak and influence decisions related to the use of the River. Forming an all women group in the communities to deliberate on water related issues was mentioned by the participants as a possible way of getting women involved in the decision making process. This opinion was expressed by two participants who in their respective views said that:

"We need to form women groups. If we have a group of women coming together, they can discuss issues and come up with possible solutions. Most at times, it is difficult for the women to speak at meetings where there are more men than women. Some of the women are shy and do not have the courage to speak at such gatherings. I will suggest that women in the communities are encouraged to form an all women group that will provide them with an environment where they can talk freely".

DISCUSSION

In this study, we found that traditional belief systems, political affiliations, religion, and other social factors continue to play a significant role in how individuals (men and women) perceive issues related to the management of the Tano River at the community level. The study revealed that, at the local level, inhabitants still embrace the customary or traditional ways of thinking about men and women. This was clear from the participants (women) who continually referred to their husbands (men) as the heads of the family and therefore should have the greater say (valued opinion) when making a decision. This notion was very clear from the female participants who were unwilling to participate in the interviews, but rather referred the researcher conduct the interview with their husbands. This could partly be explained by the traditional norms of communities where women (principally married) are not allowed to speak to strange men visiting their community. Participants from a gendered viewpoint generally framed river-related issues under three key aspects:

Emotional perspectives, physic/physique and outcome result of using a resource

On one hand, participants framed men as the agents for action (preventing wrongdoing) and on another hand as the main perpetrators of the degradation and pollution of the river. Additionally, the framing of river-related issues seem to suggest that local traditions and other belief systems continue to play a critical role in determining the responsibilities, opportunities and limitations to men and women in the decision making processes at the community level. For example, framing women as unworthy (not clean) to access water from the Tano River at a certain time can be argued as a frame that could determine women participation or not in a decision process. Again, the framing of women by their counterparts (men) as weak (not strong enough) to do certain activities as mentioned by the participants perhaps could be cited as one possible reason for women's failures to take part in discussions concerning measures to curb illegal activities that could affect the river.

Factors influencing the framing of river related issues at the community level

Many factors may contribute to how participants frame gendered issues in relation to the decision making process in the governance of a river basin. From the current study, men framed "women" based on two perspectives. First, women were framed as more concerned about water related issues and secondly, as those who can provide valuable ideas on how the river should be managed. These types of frames as presented by the participants could partly be explained by the cultural setting of the participants.

Thus in most rural communities in Ghana, rural women usually have interactions with rivers and streams on daily basis than men. Thus on daily basis, rural women at the community level fetche water for domestic activities. These general uses of water make it a valuable resource for women, hence it could be argued as a reason for their "*emotional attachment*" connection to issues related to river management.

This perhaps could be said to be a reason for the kind of framing that participants had about women as being more concerned contrarily to the latter. Again, women in their demand for water require it, in its best, clean and usable form and anything short of this affects them. It was however not surprising that this study found that women were framed differently by the men in relation to issues on the management of the river at the community level.

Furthermore, in a society (cultural environment) where traditional beliefs systems continue to play a key role in determining "*who does what and what not*", it can be argued that such realistic assumptions as equal rights for men and women as mentioned by the Un-water (2012) still remains unfounded and cannot be overemphasized. This is because, in most African traditional local communities, there are still differentiated or definitive roles for 'women' and 'men' as well as limits or restrictions to who can or cannot participate in a decision making at the local level (Cap-net and Gwa, 2006).

Thus, notwithstanding the global advocacy for equal representation of women and men in the decision making processes at all levels of society, this study has revealed that women participation continue to remain a challenge at the local level due to factors such as traditional belief (taboos) systems, socio-economic factors; overburdening of women with household activities and women's own prejudices of themselves as second to men in decision making. The participation of women in decision making may be narrow-minded by what Foucault (1982) and Bhopal, (1997) conceived as acquiescence, patriarchy or '*cultural messages'*. Such prejudices prompt women to view themselves as cautious, self-doubting and lacking the right or power to decide or contribute to a decision-making the process most at the various levels of society (O'Grady, 2005; Cornwall, 2008; 2012; 2014). This argument is analogous to Foucault's conception of a 'normalizing gaze' in which participants (in this case woman) may behave in certain ways because men framed them differently.

Despite the rhetoric of gender inclusion and as a matter of fact legislative provisions for gender inclusion in the of governance river basins (Section 6.2 of the Tano Basin Management Plan) (WRC, 2012), this study revealed that a number of impediments exist particularly for women to be recognized as key players in decision making at the community level. A major hindrance to 'women' participation as established in this study was the stereotyping of certain activities as "*men's job*" as indicated by some of the participants in the interviews. According to Cleaver and Hamada (2010), such stereotypes in a society possibly have the potential to sideline some actors (e.g. women) and to make them seem less important to the decision processes and hence their non-participation in the related activities.

Gender roles in decision making on issues related to the river at the community level

Gender roles are activities ascribed to women and men on the basis of their perceived differences. These roles tend to vary across cultures and communities and are time bound. Understanding gender roles is an important facet of resource governance because decisions must address the needs as well as the concerns of both men and women (Asaba and Fagan, 2015). Differentiating roles between men and women (that is, *what women can do or cannot do*) was evident among the participants who also correspond to the argument by Nang and Ouch (2014).

In their study, Nang and Ouch argued that contextualizing gender roles is a common phenomenon across many societies regardless of race, gender, age, class and/or ethnicity. The study showed that men and women traditionally framed different roles, challenges and control in terms of the governance processes (decision making) at the community level. From the study, the framing of men as the heads or authority at the household and community level gave them more opportunity to be involved in the decision making processes hence played a significant or conspicuous role than the women. It was evident that at the local or community level, men took control over the management, use and resolving of water-related issues more than women did. Based on this observations, it is argued by this study that women (as well as their views) are being pushed into a more weakening position (relegated to the foreground) or 'excluded'; allowing the men to provide perhaps exclusive inputs and conclusions on water-related decisions in their communities.

The observations from this study were in correspondence with the argument of Tandrayen-Ragoobur (2014). In a study on gendering governance in Mauritius, Tandrayen-Ragoobur argued that perceptions of the roles women and men play in a society as well as their access to rights and resources are often embedded in the decisions made and policies that are implemented by governance institutions at all levels. From this study, gendering roles of women and men in relation to river related issues at the community level were found to be based on traditionally preconceived meanings that have been given to men and women. Such preconceptions were found to be the issue defining frames that determined what men and women can do in terms of managing and taking decisions on the river basin at a community level. This seems to be the reason why there are still fewer women than men that take part in decision making positions at the local level of governance (Tandrayen-Ragoobur, 2014).

This current study further revealed that the participants (mostly men) support more women participating in the decision making processes particularly at the local level. The male participants in this study generally framed gender (women) and water-related issues from an optimistic perspective. These revelations from the study were in congruence with the arguments of Nang and Ouch (2014) who in their study posited that women have a deeper understanding of issues that affect water and can help resolve some of the critical issues better than men in perhaps a better, fast and peaceful manner. This study has also shown that gender plays a key role in framing issues concerning the use and management of a river and its basin. Thus women and men were found to have different frames thereby affecting how they orient their thoughts about the issues of the local community.

The general assertion by the participants in this study and the need to support the participation or inclusion of views and voices of both, women and men, in the decision making processes confirms the argument of Nang et al. (2011), That is, for a realistic or representative water governance process to occur and prevail, equal participation of women and men in the decision making processes at the community level is essential and should be embraced. Observations and revelations made by the participants during the interviews, however, seem to contradict this assertion by Nang et al. (2011). This is because the women in the local communities generally refrained (shied away) from participating in the interviews sessions. It was, however, assumed that local women still frame themselves unqualified in contributing to decisions which could be attributed to reasons that this study could not address. Cleaver (2000) suggests that how people frame the world around them also affects how far they are prepared and able to participate in and influence decision-making arrangements.

In a situation where traditional beliefs play a significant role, people frame their own actions as interconnected to the natural and supernatural world and such views according to Cleaver and Hamada (2010) are often gendered. It is argued that women at the community level may have adopted frames meant to excuse themselves from taking up extra responsibilities in addition to those they are expected traditionally to handle. This argument is in consonance with Dikito-Wachtmeister (2000) who studied the reasons for women participation or non-participation in water projects in Zimbabwe and found that women's beliefs in the existence of witchcraft shaped their willingness to partake in community decisions or not in matters of water management. However Dikito-Wachtmeister (2000) further distinguished that such frames on the part of some community members could also be a strategy to excuse themselves perhaps from time consuming water decision processes.

This notwithstanding, it is posited that when women and men in the communities fringing the Tano River basin work collectively, by sharing views through decision making processes, it could perhaps imply the creation of equal opportunities and responsibilities in contributing their views on water resources management issues. It is mentioned here that when men and women share thoughts by working together in planning the uses, access and control over the water resources, it will create a sense of ownership and responsibility among the individuals (Tracylee and Peterson, 2016).

This argument is partly supported by the Un-water (2012; 2005) in their assertion that when women and men work collectively, it creates the opportunity for addressing their specific needs as well as addressing their concerns. Perhaps when this happens, women in local communities will take decisions equally alongside their men counterparts to effectively and sustainably govern the resources in their communities.

Conditions necessary to enhance gendered perspectives in the management of the river and its basin

Usually, socially constructed ideas tend to create unequal power distribution relations amongst men and women, with men in domination (included) and women in subordination (excluded). The necessary conditions mentioned by the participants were *public education or awareness creation, the formation of women groups and the empowerment of women to take leadership positions.* The main problem with gender mainstreaming strategies particularly in a decision-making process could be the problem of a top-down approach to governance at all levels of society. The strategies as indicated by the participants can be argued to key governance areas that have seen a lot of criticisms in terms of representation of gender. These measures also correspond with the existing literature (For example, CAP-NET, GWA (2006) on gender studies which have indicated the need for empowering women through education and other support channels to enable addressing gender-related issues in our society.

Thus to achieve "equal" participation of women and men, the social order (societal way of thoughts) need to be purged by reconstructing our thoughts about 'men' and 'women' as has been predetermined by existing local customs, cultures or traditions (Amenga-Etego, 2003). It is posited that the formation of an all women groups, mass education of the general public and encouraging women by putting them in leadership roles could offer the advantage (opportunity) for women to participate without hindrances. Secondly, education, the formation of women groups and empowerment of women to take leadership positions perhaps have the potential to improve the quality of women's participation. Thus for women who are generally unfamiliar to taking up positions of authority, it is argued that considerable groundwork as indicated by CAP-NET, GWA (2006) may be needed for women to develop their self-confidence, assertiveness and skills necessary for dealing with the already established societal orders at the decision making level.

Finally, the non-participation of women in decision-making processes could also be attributed to the working arrangements of the governance processes of the community. Thus, the timing, scheduling and duration of decision making meetings at the community may not be flexible for women to double with their additional traditional or household responsibilities that they are often expected to take on (Tandrayen-Ragoobur, 2013).

Conclusion

Overall, it revealed that participants framed river related issues based on subtle viewpoints. This tends to determine the full participation of women in river basin management initiatives. However, the optimistic framing of women by men as revealed in this study did not reflect the specific roles of women in the decision making processes as women still leave the decision making in the hands of the men. Traditional beliefs, socioeconomic and domestic responsibilities of women and men were found to be some of the main factors that influence participants foaming of issues and thereby their participation in decision processes at the local/rural community level.

Gender roles though not well defined seem to be differentiated among men and women at the community level and men continue to dominate the processes of decision making. The study revealed that the participants were adequately informed about the measures or steps that could be taken to address the issue of women participation in decision making. It established that the gender dimensions in framing issues at the local community level have the potential to influence who participates in a decision process or not. Thus current river management processes at the community level can be engineered to address gendered issues with respect to the management of a river basin.

Finally, this has brought to the facade a significant area for future research consideration where researchers must endeavor to take a critical look at the issues affecting women's and men's participation in decision making to address their needs, challenges and varied concerns based on the legislative requirements that have been laid out in policy documents. Such information will be valuable for a critical evaluation of the countries performance in terms of achieving Millennium Development Goal 3 to: Promote Gender Equality and Empowerment Women.

We recommend a future analysis of the natural resource governance processes with particular focus on river bodies, protected areas and the linkage between these and food security in the catchment communities paying specific attention to climate change effects and adaptive capacities of the local inhabitants in these local communities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Effect of cocoa farming intensification on biodiversity and ecosystem properties in southern Ghana

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We investigated the effect of cocoa farming on biodiversity and ecosystem services under different cocoa management systems. The study was carried out in three cocoa producing districts in southwestern Ghana using Y-frame sampling scheme. Five 25 m × 25 m size plots were demarcated at 100 m intervals along in the cocoa farms and the natural forest reserves. Fifteen plots were demarcated in the cocoa farms per community giving a total of 90 plots. Significant decrease in tree species diversity and soil microfungi diversity were recorded in the intensive cocoa farmland compared traditional cocoa and natural forest. Soil invertebrate species diversity was high in traditional cocoa farms than in natural forest. Shaded litter fall production declined in the different cocoa management systems. Total nitrogen content and phosphorus were high in intensive cocoa farms and low in the natural forest. Soil organic carbon was high in the natural forest and low in the intensive cocoa farms. Total litter mass was high in the traditional cocoa farms and low in natural forests. The magnitude of carbon stocks decrease in the cocoa farms compared to the natural forest. For a successful cocoa production, shaded cocoa agroforest system must be encouraged in order to ensure biodiversity conservation, ecosystem services and a sustainable management of cocoa farmlands to check global climate change.

Key words: Agricultural intensification, biodiversity conservation, ecosystem services, deforestation.

INTRODUCTION

Tropical rainforests cover only about 7% of the earth's land surface and they are estimated to contain at least one-third of global biodiversity (Kammesheidt, 2002). They also maintain and support ecosystem services that are essential for human wellbeing (MEA, 2005). Unfortunately, over the years, human population growth and the need for agricultural expansion has led to increasing deforestation rates especially in the tropics (Dobson et al., 1997). The consequences of these agricultural expansions are not only reduced soil fertility but also include significant loss of biodiversity (Primack and Corlett, 2005) and associated ecosystem services or

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properties. In Ghana and other West African countries, majority of the rural population depend on agriculture as a source of livelihood (Dobson et al., 1997). However, some farming practices such as slash and burn, shifting cultivation and monoculture methods have been found to be unsustainable and harmful to the environment (Quansah et al., 2001). The persistent adoption of these farming practices coupled with the rapidly growing population has resulted in high demands for extra land for agricultural production.

Traditionally, cocoa is grown under diversified native tree shade, increasingly viewed as a means of contributing to biodiversity conservation within agricultural landscapes (Rice and Greenberg, 2000; Schroth et al., 2004) and complementing conservation in protected areas. These traditional plantations are enriched by non-timber forest products (Duguma et al., 2001) and maintain many of the ecological characteristics of natural forests.

Today, the traditional polyculture cocoa production system is giving way to full sun cocoa production. Full sun cocoa production is the thinning or complete removal of shade trees from cocoa farms. According to Tondoh et al. (2015), full-sun cocoa farming is currently the most widespread cocoa cultivation system in humid and sub-humid regions of the world. In recent times, full-sun cocoa farming have resulted in a drastic loss of forest plant species that are replaced by pioneer and exotic species (Asase et al., 2009; Oke and Odebiyi, 2007; Zapfack et al., 2002; Dumont et al., 2014). The attraction of full-sun cocoa production is clearly the ability to increase yields and therefore increase the economic benefits of cocoa production in the short-term. Yet full-sun cocoa provides very little benefit in terms of biodiversity conservation and produce for a shorter amount of time than shaded cocoa farms (Schroth and Harvey, 2007).

In southern Cameroon, where much pristine forest remains, cocoa production has contributed immensely to deforestation at the forest agriculture interface because cocoa acreage is increasing due to the international market price recovery (ICCO, 2006). However, despite the fact that some studies have focus on the impact of cocoa farming on vegetation structure in Ghana (Asase et al., 2009), (Zapfack et al., 2002) in Cameroon and (Tondoh et al., 2015) in Cote D'Ivoire, yet not much has been investigated on the conversion of forest to cocoa farmlands on different biodiversity groups and ecosystem services in South western Ghana. Particularly, data on potential tradeoffs between biodiversity loss and agricultural intensification including habitat conversion are lacking. This information is important in making strategic management plans toward conserving biodiversity and ensuring ecosystem services whiles increasing the profitability of cocoa farmers. We examined the consequences of the conversion of natural forest to cocoa farmlands on biodiversity and ecosystem services in southwestern Ghana. We hypothesized that all cocoa farms were derived from adjacent natural forests and that biodiversity and ecosystem properties are deteriorated as a result of cocoa farming. Specifically, the study was designed to address the following questions: (1) How does cocoa farming affect biodiversity and ecosystem properties? (2) Which biodiversity groups and ecosystem properties are mostly affected by cocoa farming intensification?

MATERIALS AND METHODS

Study area

The present study was carried out in three cocoa producing districts in southwestern Ghana, namely; Twifo-Heman Lower Denkyira district, Bia district and Atwima-Mponua district (Figure 1). Mean monthly temperature in the study sites is between 24 and 30°C. There are two major rainfall seasons within the year. Annual rainfall for the major season is about 1200-1850 mm while rainfall for minor season is 1000-1250 mm per year. The natural vegetation in the study sites varies from wet semi equatorial to moist semi deciduous forest (Forestry Commission, 2010). However, natural vegetation in the study sites has been extensively cleared to form a strongly agricultural area populated largely by communities of smallholder cocoa farmers (Forestry Commission, 2010). The geology comprises of the sites consist of Lower Birrimian rock series- a pre-Cambrian formation that dominates Ghanaian forest zone (Forestry Commission, 2010).

Sampling procedure

Sampling of cocoa farms was carried out in two randomly selected communities in the three cocoa growing districts. To take into account soil and landscape variability in cocoa farms, we adopted a Y-frame sampling scheme (Henry et al., 2009). We randomly chose a geo-referenced point in each community to locate the centre of the Y-frame and with the aid of a Global Positioning System (Gramin eTrex 20) and a compass, the three arms of the Y-frame diverting at 120° were located (Figure 2). The length of each 3 arms of Y-frame was 500 m. We demarcated 5 plots each of size 25 m × 25 m at 100 m intervals along each of the three arms of the Y-frame. Thus 15 plots were demarcated in cocoa farms in each of the 6 communities giving a total of 90 plots.

In order to compare cocoa farms with the natural forest from which they were derived, we sampled adjacent forests reserves to the community. The selected adjacent forest reserves were Kakum National Park, Bia Conservation Area and Tano Offin Forest Reserve. Within each of the three selected forest reserves, we demarcated three parallel transects of length 500 m and separated at least 200 m from each other. We also demarcated 5 plots each of size 25 m × 25 m along each transect at 100 m intervals. Thus a total of 45 plots were demarcated in the natural forest- 15 plots in each forest reserve.

Biodiversity

We sampled trees following the protocol used in the recent study of Asase and Tetteh (2010). All trees with diameter- breast-height (DBH) ≥ 5 cm (1.3 m above ground level) within the 25 m × 25 m plots were enumerated. The trees with the specified DBH range

Figure 1. Map of Ghana showing the locations of the study sites.

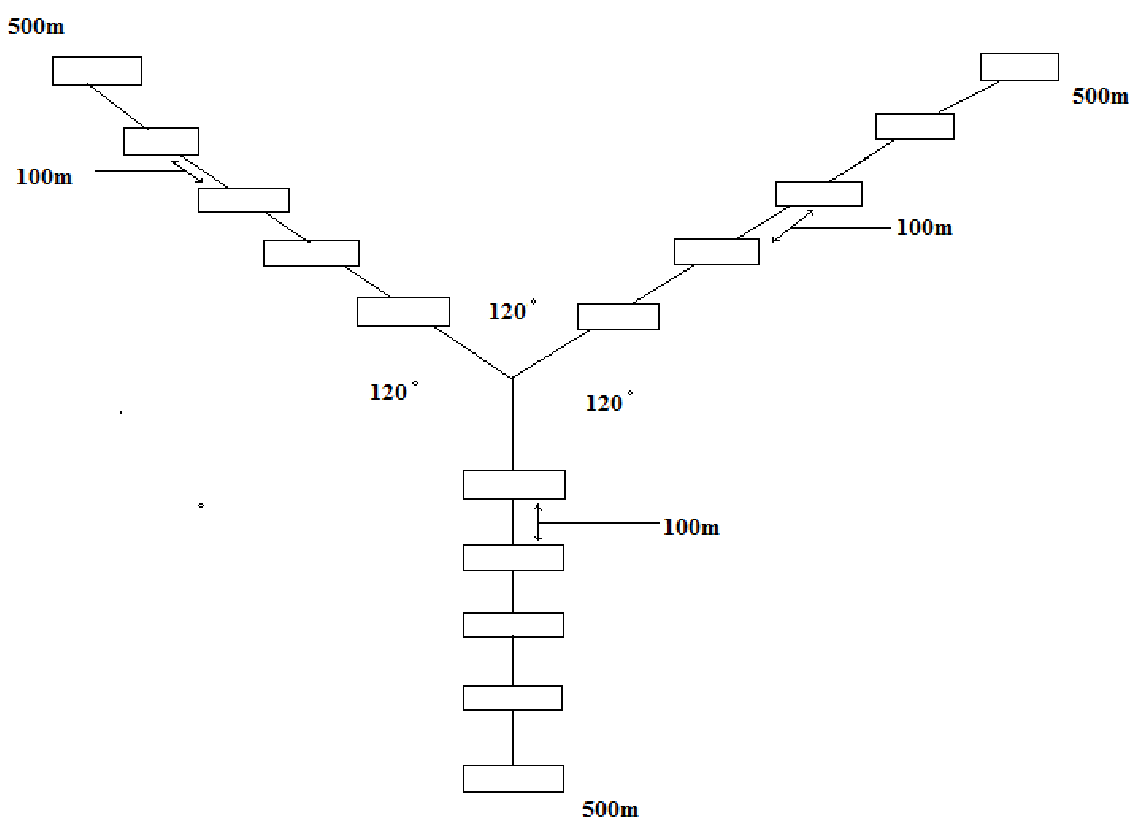

Figure 2. A diagram showing Y-frame sampling strategy adopted in cocoa farms.

were individually identified to species level and their DBH measured. We identified forest trees species encountered using the field guide of Hawthorne and Jongkind (2006). For soil biodiversity, we studied invertebrates and microfungi biodiversity. We randomly selected 20 plots in cocoa farms in each community and 10 plots in each forest reserve for the study of soil invertebrates. Thus a total of 90 plots were used; 60 in cocoa farms and 30 in natural forest. Two pitfall traps (diameter = 9 cm, height = 12 cm) were sunk 5 cm deep inside each 25 m × 25 m plot and traps were separated at least 5 m apart. Captures were preserved in 70% alcohol and subsequently counted and identified under a binocular microscope with assistance of experts at Department of Animal Biology and Conservation Sciences, University of Ghana. Species identification was confirmed (Blair et al., 1996). Sampling of soil microflora biodiversity involved collection of two core samples in each plot from the first 0-10 cm soil depth. The microflora in the core soil samples were studied using the modified Cook's medium (Cooke, 1954) following the using the pour plate method (Alexopoulos and Beneke, 1962). Species of microflora were identified and counted with the aid of mycologists from the Department of Plant and Environmental Biology at the University of Ghana.

Litter mass production

We monitored the amount of litter mass production over a period of one year from May, 2012 to April, 2013 in cocoa farms and natural forest using litter trap (1.0 × 1.0 × 0.2 m raised 50 cm above the ground). We randomly selected 10 plots in one of the two studied communities per district and 10 plots in each forest reserve. In total, 60 L traps were studied; 30 in cocoa farms and 30 in natural forest. We randomly placed one litter trap per plot but making sure that the traps were not placed not directly under trees. Litter intercepted by the traps was emptied monthly and sorted out into shaded tree leaf litter, cocoa leaf litter, flowers and twigs, and subsequently oven-dried at 73.5°C until constant weight.

Soil physical and chemical properties

Soil samples were collected from the first 0 -15 cm depth from two randomly selected spots in each plot. The minimum distance of collection between the two spots within plots was 5 m. The soil samples collected from the same plot were bulked together, air-dried, ground and sieved through a 2 mm mesh size sieve before determination of physical and chemical properties. Soil bulk density was determined using the core method (Blake, 1965) as detailed in Asase et al. (2009). The Boyoucous hydrometer method using calgon as dispersant (Boyoucous, 1965) was used to determine soil texture. Soil pH was determined using the distilled water procedure (McLean, 1982). Total nitrogen was quantified using the Kjeldahl method (Bremner, 1965) and available phosphorus content determined following Bray 1 method (Bray and Kurtz, 1945 cited in Ofori-Frimpong et al., 2010) while exchangeable potassium was determined using flame emission photometry (FEP) as described in studies by Dorgbetor et al. (2012).

Estimation of tree biomass and carbon stocks

To estimate above ground tree biomass, four allometric equations were used. For native forest trees, biomass was estimated using the allometric model of Henry et al. (2010) which estimates tree biomass as $Y= 0.30 \times DBH^{2.31}$,where Y is tree biomass and DBH is diameter at breast height. This model was specifically developed based on Ghanaian forest trees. Cocoa tree biomass was estimated using the model $\rho i\ ^{-\ exp}(-1.499 + 2.148\ \ln(DBH) + 0.207(\ln(DBH))^2 - 0.0281(\ln(DBH))^3$ of Chave et al. (2005). Mean biomass of palm from a previous study (Thenkabail et al., 2004) was used as the biomass value of all individual palm species encountered as a result of the lower DBH to biomass ratio of palm compared with other tree species (Wade et al., 2010). Aboveground biomass of banana and plantain (*Musa* species.) was estimated using the following empirical model $0.03 \times d^{2.13}$ (Arifin, 2001). The DBH values of trees measured during the enumeration of trees were used for the calculations. Roots biomass was estimated indirectly from the above-ground carbon biomass following the method of Cairns et al. (1997) which estimates root as 24% of above-ground tree biomass. Finally carbon stock of trees was calculated by multiplying tree biomass estimated by 0.5 (Glenday, 2006).

For calculation of soil organic carbon stock (SOC), percentage carbon content and bulk density of soil was determined for each plot. Collection of soil samples and initial preparation was as described above. The percentage carbon content of soil was determined using a modification of the wet-combustion method as detailed in Asase et al. (2009) and bulk density using the core method as described above. SOC was calculated as, SOC = % C x bulk density x soil depth (Kirby and Potvin, 2007). In order to account for differences in soil bulk densities between the natural forest and cocoa farms, the thickness of soil layer beneath the cocoa farms was adjusted as described in Tondoh et al. (2015).

Classification of cocoa farms

Cocoa farms were classified into intensive and traditional cocoa based on percentage shade cover. Shade intensity was measured with a hand held concave spherical densitometer. Following Wade et al. (2010), an arbitrary classification of < 25% shade cover was considered to be 'intensive' and ≥ 25% shade was considered 'traditional'.

Species richness and similarity index

The rarefaction method (Gotelli and Colewell, 2001) was used to generate the expected number of species (trees, soil invertebrate and soil microfungi) in the traditional cocoa farm, intensive cocoa farm and the natural forest. The free software Estimates 8.0 (Gotelli, 2006) was used to generate data for the construction of sample based rarefaction curves and 95% confidence limits for species richness. Species diversity was evaluated using the Shannon –Wiener index ($H^1=\sum^{S}_{i=} ln\ pi$), where s is the total number of species and p is the relative abundances of the I species. In contrast to direct measures of species richness, this index takes into account the relative abundances of species (Legendre and Legendre, 1998). Species compositional similarity between land use types was estimated using the Jaccard similarity index. The Jaccard similarity index uses species presence/absence data for two sample sets (in this case land-use types) and is calculated as $J = M/(M + N)$, where M is the number of species that occur in both land-uses and N is the number of species that occur in only one of the land-use types.

Statistical analysis

Statistical differences in means of stem density, carbon stocks, litter mass, soil physical and chemical properties were analyzed using analysis of variance (ANOVA). Normality test for homogeneity of variance was determined using Shapiro-Wilk test (Crawley, 2007). Where the test indicated significant difference, means were contrasted with post hoc Tukey HSD test. The R software version 3.1.1 was used.

Table 1. Biodiversity (Trees, soil invertebrates and soil microflora diversity) and structural characteristics of non-crop trees in the three land use types.

Parameter / Tree diversity	Natural forest	Traditional cocoa	Intensive cocoa
Number of individuals	726	111	72
Number of species	84	57	36
Shannon Weiner index(±SE)	3.5±0.02	0.63±0.005	0.76±0.008
Stem density ha-^{1}	22.9±1.69	3.8±1.32	2.4±0.89
Basal area of trees m^2ha^{-1}	29.3±6.8	9.4±5.3	6.6±3.6
Soil invertebrate			
Soil invertebrate density (ha^{-1})	16.7±5.7	39.26±14.7	20.3± 18.9
Number of individuals	500	1012	658
Number of species	28	27	25
Soil microflora			
Number of individuals	1709	823	718
Soil microflora Relative density (ha^{-1})	13.3±5.7	10.2±6.2	5.2±4.2
Number of species	13	12	12

RESULTS

Biodiversity

In total, 909 individual non-cocoa trees belonging to 100 species in 26 families were identified. Individual-based rarefaction curve showed that tree species richness was significantly higher in natural forest and least in intensive cocoa at 95% confidence limit (Figure 2). Mean Shannon–Weiner diversity index differed among the land use types ($p < 0.001$) with the largest diversity recorded in the natural forest (3.5±0.02) but comparable level of diversity between traditional cocoa farms (0.76± 0.008) and intensive cocoa farms (0.63±0.005). The β-diversity statistics showed that non-crop tree species community in the intensive and traditional cocoa farms are most similar (Jaccard index = 0.54) followed by that between the natural forest and traditional cocoa farms (Jaccard index = 0.32). The least non-crop tree species composition similarity was found between the natural forest and intensive cocoa farms (Jaccard index = 0.012). Density of non-cocoa trees decreased significantly ($p < 0.001$) from natural forest (22.9 ± 1.69 ha^{-1}) through traditional cocoa (3.8 ± 1.69 ha^{-1}) to intensive cocoa (2.4 ± 0.89 ha^{-1}). Post hoc Tukey HSD test showed significant difference in mean density of native forest trees between the forest reserves and intensive cocoa farms (Tukey HSD, $p < 0.0001$) and between the forest reserves and traditional cocoa farms (Tukey HSD, $p < 0.001$). Basal area of forest trees was highest in the forest reserves (29.3 ± 6.9 m^2ha^{-1}) and lowest in the intensive cocoa farms (6.6 ± 5.3 m^2ha^{-1}) (Tables 1 and 2). Basal area of forest trees differed significantly in the different land use types ($p < 0.001$). There were however, significant differences in tree basal area between forest reserves and intensive cocoa farms (Tukey HSD, $p < 0.001$), and between forest reserves and traditional cocoa farms (Tukey HSD, $p < 0.001$). The basal area of trees between intensive cocoa farms and traditional cocoa farms was, however, not significant (Tukey HSD, $p > 0.05$).

For soil invertebrates 2,168 individuals belonging to 39 species were identified. Of the species identified, the most common were *Camponotus chrysursus* Apellis Wheeler *Camponotus* sp, *Canthon pilularis* L., *Oncopeltus fasciatus* Bonhag, *Palthothrus* sp, *Peridontopygne* sp and *Gryllus lucens* Wlk. Sixteen of the species were identified in both dry season and wet season although about 75% of the species were detected in only dry season. Mean Shannon–Weiner diversity index varied among the land use types ($p < 0.001$) with the largest diversity recorded in traditional cocoa farms (2.21± 0.004) followed by (2.02±0.003) in the intensive cocoa farms. The least mean Shannon –Weiner index (1.74±0.02) was found in the natural forest reserves. The soil invertebrate species community in the traditional cocoa farms and intensive cocoa farms were most similar (Jaccard index =0.79), followed by that between traditional and natural forest reserves (Jaccard index= 0.68).The least similar in terms of tree species composition was the natural forest and intensive cocoa farms (Jaccard index = 0.65). Soil invertebrate species richness was significantly higher in the traditional cocoa farms compared to the intensive cocoa farms and natural forest at 95% confidence limits (Figure 3 and 4). The density of soil invertebrate varied significantly among the land use types ($p < 0.001$) and was highest in 39.2 ± 14.7

Table 2. Biodiversity, litter mass, soil characteristics and carbon stocks in the different land use types

Parameter / **Tree diversity**	**Natural forest**	**Traditional cocoa**	**Intensive cocoa**	**Statistical methods of comparison of means (post pair-wise comparisons)**
Forest trees	22.9±0.53	3.6 ± 0.74	2.9 ± 0.77	ANOVA,P < 0.0001
Cocoa trees	-	18.3 ± 6.77	19.1± 7.01	ANOVA,P < 0.0001
Soil invertebrate	16.7± 6.5	33.1±8.9	23.5±9.3	ANOVA, P > 0.05
Soil microfungi	11.2±1.5	7.7±2.1	4.7±2.2	ANOVA, P < 0.05
Litter mass				
Shade / forest tree leaf litter	13.2 ±0.51	0.78 ± 0.72	0.73 ± 0.72	ANOVA,P < 0.0001
Cocoa leaf litter	0	17.2 ± 1.21	17.9 ± 1.21	ANOVA,P < 0.0001
Flower litter	0	0.10 ± 2.8	0.08 ± 2.8	ANOVA, P< 0.001
Twigs litter	0	1.48 ±2.21	1.77 ±2.21	ANOVA,P < 0.001
Total litter	14.6 ±1.21	20.6 ±1.71	19.8 ± 1.71	ANOVA, P< 0.0001
Soil characteristics				
Soil pH(water) -log H^+	6.6 ± 0.16	6.6 ± 0.22	6.9 ± 0.23	ANOVA, P > 0.05
% Total N	0.18 ±0.004	0.19 ±0.007	0.18 ±0.006	ANOVA, P > 0.05
Available P µg/g	8.5 ± 1.19	16.9 ±1.64	18.6 ± 1.72	ANOVA, P< 0.0001
% C	3.5 ± 0.17	2.4 ± 0.23	2.3 ±0.24	ANOVA, P <0.0001
Carbon stocks				
Shade / forest trees carbon	311.2 ±8.3	126.5 ± 11.5	99.3 ± 11.9	ANOVA, P < 0.0001
Cocoa tree-stored carbon	-	26.9 ± 2.0	27.7 ± 2.1	ANOVA, P< 0.0001
Soil litter carbon (0-15 cm)	3.4 ± 0.20	2.6 ± 0.28	2.4 ± 0.29	ANOVA, P< 0.001
Total carbon stock	319.6 ± 8.6	160.4±12.0	132.0 ± 9.4	ANOVA, P < 0.001

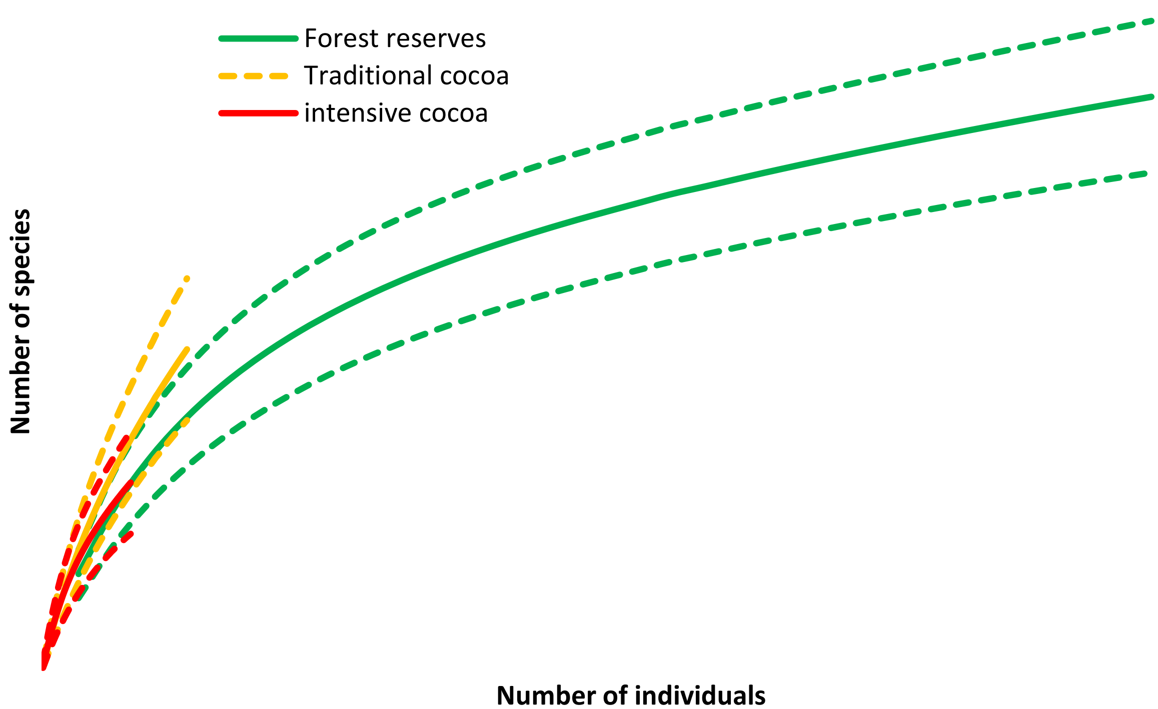

Figure 3. Species accumulation curves (with upper and lower 95% Confidence Limits (CI) as shown in broken lines for non-crop tree ≥ 5cm dbh in the three land use type.

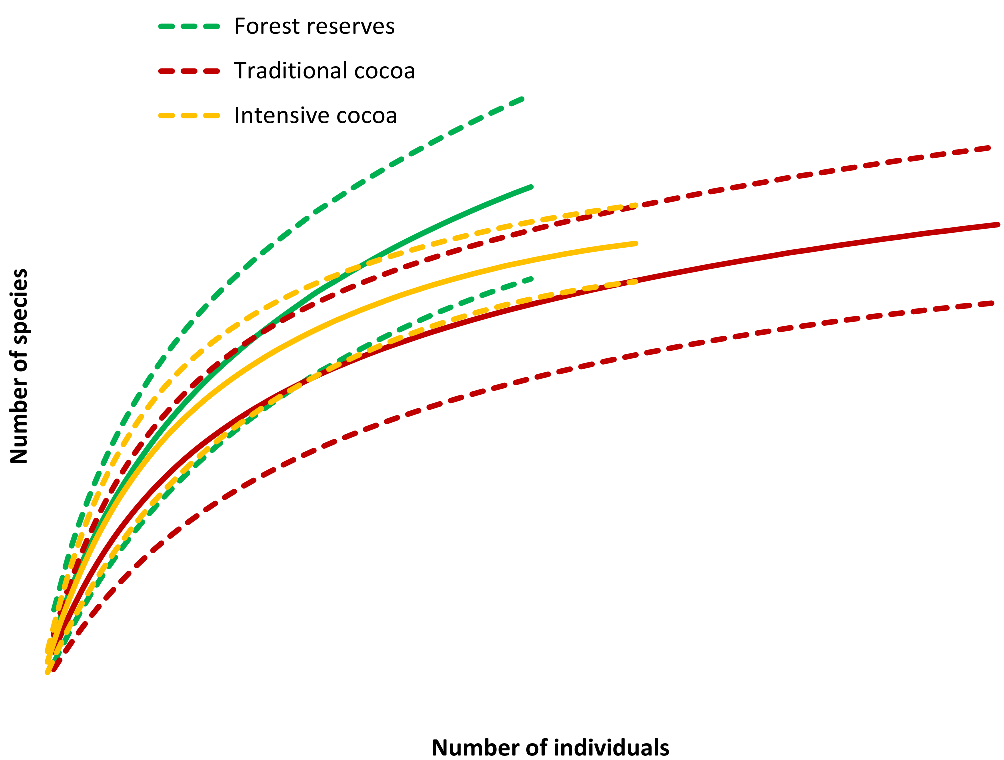

Figure 4. Species accumulation curves (with upper and lower 95% Confidence Limits (CI) as shown in broken lines for soil invertebrates in the three land use types.

ha^{-1} traditional cocoa farms and lowest in 9.5 ± 5.2 ha^{-1} natural forest reserves.

A total of 3,250 individual colonies of soil microflora belonging to 13 species in 8 families were identified. The familes Trichocomaceae (6 species) and Loculoas-mycetes (2 species) contained the largest number of species. Twelve of species encountered, namely, *Aspergillus flavus* Link, *Aspergillus niger* Van Tieghem, *Aspergillus fumigatus* Stammberger, *Aspergillus sulpherous, Aspergillus wentii* Schuster, *Candida albican* Hoyer, *Cladosporium herbarum* Pers, *Mycelia sterilia, Neurospora sitophilia* Shear, *Penicillium oxalicum* Currie and Thom, *Rhizopus stolonifer* (Ehrenb)Vuill and *Trichoderma viride* Bonn were found in all the three land use types. Mean Shannon–Weiner diversity index differ among the land use types with largest diversity found in the natural forest reserves (2.63±0.008) while the least was recorded in the intensive cocoa farms (2.15±0.007). Soil microflora community in the intensive and traditional cocoa farms were most similar (Jaccard index = 0.95) followed by that between traditional cocoa farms and natural forest reserves (Jaccard index = 0.92) whiles the least was found between the intensive cocoa farms and natural forest reserves (Jaccard= 0.85). Relative density of soil microflora was highest (9.3± 3.3 m^2 ha^{-1}) in forest reserves and lowest (1.8 ± 0.4 m^2 ha^{-1}) in intensive cocoa farms and did not differ significantly among the land use types ($p > 0.05$).

Litter mass production

Total annual litter mass was highest (14.6± 1.21 kg/ha) in natural forest and lowest (19.8 kg/ha) in intensive cocoa. Total litter mass varied significantly across the different land use types ($p > 0.05$). Significant difference in litter mass was detected between natural forest and intensive cocoa (Tukey HSD, $p < 0.01$), and between natural forest and traditional cocoa (Tukey HSD, $p < 0.01$) but no significant difference was detected between intensive and traditional cocoa farmlands (Tukey HSD, $p = 0.87$). Shade tree litter mass was highest (13.2±2.3 kg/ha) in the natural forest and lowest (0.99± 0.9 kg/ha) in intensive cocoa farms but varied significantly ($p < 0.001$) in the three land-use types. Conversely, cocoa leaf litter was highest (29.1 ± 6.5 kg/ ha) in intensive cocoa farms and lowest (26.2 ± 3.2 kg/ ha) in traditional cocoa farms. The quantity of cocoa leaf litter mass produced showed significant difference ($p < 0.001$) among the different land use types.

Soil physical and chemical characteristics

Soil pH levels were highest in intensive cocoa farms (6.9±0.23) and lowest in the natural forest reserves (6.6±0.16). Total N content were highest (0.19 ± 0.01) in intensive cocoa farms and lowest (0.18±0.00) in the forest reserves. Soil organic carbon was highest (3.5 ±

0.17) in forest reserves and lowest (2.3 ± 0.24) in intensive cocoa farms but varied significantly ($p < 0.001$) across the different land use types. Available P content was highest (20.0 ± 3.8 µg/g) in intensive cocoa farms and lowest (8.5 ± 2.8 µg/g) in forest reserves. Available P content was however, significant among the different land use types ($p < 0.001$). Mean exchangeable K content found in the traditional cocoa farms was about twice that found in intensive cocoa farms.

Carbon stocks

Total carbon stocks was highest (319.6 ±8.6 Mg / ha) in the natural forest and lowest (132.0 ± 12.4 Mg / ha) in the intensive cocoa farms but varied significantly among the land use types (ANOVA, $p < 0.001$). Post hoc TukeyHSD test showed significant difference in the mean total carbon stock of trees between intensive cocoa farms and forest reserves (Tukey HSD, $p < 0.001$) and between traditional cocoa farms and forest reserves (Tukey HSD, $p < 0.001$). Forest trees carbon stock was highest (311.2 ± 8.3 Mg/ha) in forest reserves and lowest (99.3 ± 11.9 Mg/ha) in intensive cocoa farms and varied significantly among the different land use types (ANOVA, $p < 0.001$). Cocoa trees carbon stock was highest (27.7 ± 2.8 Mg/ha) in intensive cocoa farms and lowest (26.9 ± 2.7 Mg/ha) in traditional cocoa farms. Cocoa trees carbon stock showed significant difference among the land use types (ANOVA, $p < 0.001$). Mean palm tree carbon stock found in the forest reserves was about twice that found in the intensive cocoa farms. Plantain and banana tree crop carbon decrease significantly (ANOVA, $p > 0.05$) in the traditional cocoa (1.8 ±3.9 Mg/ha) and intensive cocoa farms (0.86± 4.0 Mg/ha).

Mean soil organic carbon stock per plot varied significantly among the different land use types (ANOVA, $p< 0.001$). Natural forest contained the largest average carbon stock per unit area with a mean value of (3.4 ± 0.4 Mg/ha) and lowest (2.5 ± 0.2 Mg /ha) in intensive cocoa farms. Post hoc TukeyHSD test showed that soil organic carbon between forest reserves and intensive cocoa farms was significant (TukeyHSD, $p < 0.01$) and between forest reserves and traditional cocoa farms (TukeyHSD, $p < 0.01$). However, between intensive and traditional cocoa farms, there was no significant difference observed (TukeyHSD, $p= 0.97$).

DISCUSSION

Biodiversity

The results of the study showed that the conversion of natural forest to cocoa farmlands and subsequent intensification has impacted negatively on forest tree species diversity. Similar trends have been observed in other studies in Ghana (Asase and Tetteh, 2010; Asase et al., 2009) and elsewhere (Tondoh et al., 2015; Bobo et al., 2006; Zapfack et al., 2002 and Sonwa et al., 2007). The Shannon Wienner index found in this study was not similar to what was reported by Tetteh (2009) in cocoa dominated and mixed food crop agroforest in Ghana. The loss of tree species within the cocoa farmlands may affect the conservation of other biodiversity such as birds, insects and rodents to a greater extent. This may also lead to the migration of certain important fauna species to other ecosystems for safety and thus a decrease in general biodiversity within the cocoa farmlands. Average density of non-cocoa trees in intensive cocoa farmland was low compared to the traditional cocoa farm. This observation is in line with previous study conducted by Wade et al*.* (2010) who reported higher density of non-cocoa tree species in traditional cocoa farms than in intensive cocoa farms. Basal area of forest tree species clearly decreases from the traditional cocoa farms to the intensive cocoa farms. The basal area of tree species recorded in this study was lower than what was found in Southern Cameroon (Zapfack et al., 2002). This is evident of how cocoa management intensity has contributed to the drastic loss of forest tree species over time.

The results of the study showed variations in soil invertebrate species diversity in the different study areas. The diversity of soil invertebrate generally increased with habitat complexity, the lowest being in natural forest and the highest in traditional cocoa farms. Similarly, studies of Hill et al. (1995) demonstrated a reduction in diversity following more extreme forms of forest disturbance. The lower diversity in the intensively managed cocoa farms could be due to lack of habitat heterogeneity and food resources compared to the traditional cocoa farms. The higher diversity of species observed in the traditional cocoa farms reinforce the idea that cocoa agroforestry systems may be considered as a conservative land use system (Moco et al., 2009; Rahman et al., 2011). The presence of these soil invertebrates in the cocoa farms probably might be due to certain factors favourable to the insect species through microhabitat conditions. Decaying matter-wood, banana stems, cocoa leaf litter, and cocoa pod husks (at the pod-breaking points) on the farms might have provided a variety of microhabitats which accommodated the different insect species.

Soil microflora species diversity declined drastically in the intensive cocoa farms than in the forest reserves. This observation is in line with previous report by Tetteh (2009) who found higher diversity of soil microflora in natural forest than in cocoa and mixed food crop agroforest. This implies that soil microflora diversity is a requirement for the decomposition of litter essential for the release of organic compounds necessary for plant growth.

Litter mass and characteristics

Total litter mass decreased significantly in the cocoa farmlands than in the forest reserves. This observation is in line with studies conducted by Ofori-Frimpong et al. (2010) and Owusu-Sekyere et al. (2006). In the cocoa farmlands, shaded litter was very low due to the destruction of the shaded trees by farmers and cocoa merchants purposely for timber. The conversion of shaded cocoa farmlands to cocoa monoculture mostly affects species diversity and the nutrient cycling process. Cocoa litter production contributed to the highest proportion of total litter mass in the cocoa farmlands.

Soil characteristics

Generally, the soils were slightly acidic to neutral in nature supporting the cultivation of crops such as cocoa (*Theobroma cacao*), plantain (*Musa paradisca*), banana (*Musa sapientum*) and palm oil (*Elaies guinenesis*). Soil organic carbon showed a decreasing pattern in the cocoa farmlands compared to the forest reserves. This assertion is similar to recent study conducted by Ofori-Frimpong et al. (2010) who observed high organic carbon content in forest reserves than in cocoa farmlands. In the cocoa farmlands total nitrogen and available phosphorus contents were high due to the continuous application of chemical fertilizers to the cocoa trees as recommended by the Cocoa Research Institute of Ghana. The low levels of total nitrogen and available phosphorus contents found in the forest reserves could be attributed to leaching of nutrients from the forest floor.

Conclusions

From the study it can be concluded that tree species diversity in the cocoa farmlands decreased with increasing management intensity affecting, stem density, basal area, litter fall production and subsequent reduction in above and below carbon stocks. Soil microfungi species diversity also decreased in the cocoa farmlands compared to the natural forest. However, soil invertebrate species diversity was high in the traditional cocoa farms than in the forest reserves. To ensure a sound ecosystem, biodiversity conservation and higher productivity, shaded cocoa agroforest system should be encouraged in order to ensure sustainable management of cocoa farms to check global climate change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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