

Assessment of Tree Diversity of Riparian Forest Fragments in Omo Biosphere Reserve, Ogun State, Nigeria

Olatidoye O. R. Olatidoye (✉ olaremiolatidoye@gmail.com)

Forestry Research Institute of Nigeria

Isichei A. O. Isichei

Obafemi Awolowo University

OYELOWO O.J. OYELOWO

Forestry Research Institute of Nigeria

Koyejo O. A. Koyejo

Forestry Research Institute of Nigeria, Humid Research Station

Kambi C. Kambi

Federal College of Forestry

Jeminiwa O.R. Jeminiwa

Forestry Research Institute of Nigeria

Research Article

Keywords: Tree diversity, biodiversity protection, Major rivers and Streams

Posted Date: April 20th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-2832142/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Frequently discontinuous landscapes are attributed to various unsustainable human activities all over the world. These activities result to poorer diversity and reduced quite a lot of landscape

The study was laid out on various sites of the stratified zone of the reserve namely: Core, Buffer and Transition. Riparian forests along Major River and Streams were sampled. Ninety plots (25m × 25m) were selected for the study. Sites were chosen based on accessibility within the zones and it was ensured that a variety of physiognomy were well represented.

In all, 74 tree species, 31 families 65 genera were identified. Shannon index varied from 2.17 to 3.036, evenness of the riparian tree species was 0.056 and Sorensen index was 90.5%. The Core zone of the reserve has the highest occurrence of riparian and upland tree species in comparison with the buffer and transition zone. *Diospyros dendo* is the most occurring species in the core zone and more species were found along major rivers. In the buffer zone, tree species along the stream had higher representation with *Cleistopholis patens* observed while in the transition zone, higher diversity was found in species along the major rivers with *Theobroma cacao* having the highest occurrence.

This study shows that the composition and plant community structure is affected by a range of disorders such as frequencies and magnitude of human activities at different levels. Species along streams had higher abundance than those along Major Rivers due to low intensity in the rate of flow of water which enables inundation and support of seed settlement for germination.

Introduction

The activities of humans have frequently fragmented landscapes across the world (Haddad et al. 2015). Rapid changes in land use have led to the advanced destruction and fragmentation of riparian forests which provide fertile soil for cultivation, give prospects for irrigation and serve as accommodation to a wide range of valued and rare plants and animals. Therefore, riparian forests are methodically aimed at for illegal selective tree cutting, hunting and conversion to agriculture which has led to their degradation. Riparian forests have repeatedly been disregarded or excluded from general vegetation studies in favour to upland forests as a result of accessibility to the terrain (Natta 2003). However, considerable uncertainty remains in our knowledge of riparian forest flora specifically the diversity, ecology and spatial distribution of species in the riparian forests. Humans modifications affect riparian vegetation directly and indirectly through land conversion and regulation of the hydrological regime. For example, in Greece only 10% of riparian corridors can be considered as near natural conditions. (Chatzinikolaou et al. 2011). The riparian ecosystems appear to be especially vulnerable because of cumulative impacts of these modifications, together with additive effects of climate change. (Perry et al. 2012). Direct impacts of grazing, fire regime modification, cultivated agriculture and plantations, and urbanization may reduce riparian cover, influence floristic composition, and/or facilitate increased nonnative species frequency and cover. (Meek et al. 2010). Human influences are the major causes affecting riparian forests both in structural complexity and size in decades or centuries which have resulted in a poorer diversity and reduced quite a lot of landscape. Their rich biological resources, especially plant species, are declining before they can be inventoried and assessed (Natta 2000). The concern in riparian forests is embedded in the resources found in them basically fertile and moist soils, water, wood and non-timber forest products that are utilised by neighboring populations to satisfy their basic needs and as source of income.

Material And Methods

Study area

The study area, Omo Biosphere Reserve is an internationally recognised and unique habitat whose landscape has been partitioned as a result of biological population protection to meet up with the requirement of a typical biosphere reserve. It stretches North from latitudes 6° 35' to 7° 05' N and East longitude 4° 19' to 4° 40' E in Ijebu area of Ogun State, Southwestern Nigeria (Fig. 1). This study was carried out within the zonation of the reserve viz: The core (Strict Nature Reserve), the buffer zone and the transition zone within Omo Biosphere Reserve in Ogun State, Southwestern Nigeria.

The core zone covers about 460 hectares. The buffer zone surrounds the core area with an area of 8,165 hectares while the transition zone trans-borders the buffer zone and covers an area of 666,498.75 hectares. Each of these zones are separated by forest road, foot path, river streams or enclaves. Riparian areas within the biosphere consist of vegetation's along major rivers, streams and wetlands. Representative sites were chosen along the major river, streams and Upland in each of the core, buffer, and transition zone. Figure 1 shows the map of Omo Biosphere Reserve

A total of 90 plots (25 m × 25 m) was selected for the study. Thirty plots each was sampled along the riparian vegetation (in the core, buffer and transition) out of which 15 were sampled along the riparian forest and 15 plots for the adjacent upland vegetation in each zone. All the tree species within plots were identified with the help of a taxonomist, recorded and assigned to families.

The occurrence of each tree species was obtained. The species diversity (number of species in a family) was obtained for tree species diversity classification. The height of trees were measured using Haga Altimeter. The diameter at breast height of trees with a dbh of 10 and above (dbh ≥ 10) at 1.3 m above the ground were measured using a tape and recorded to calculate estimates of timber volume and basal area. Differences in site diversity index (Shannon), Equitability index (Pielou) and Sorensons diversity index were calculated.

Species Diversity Index: This was calculated using the Shannon-Wiener diversity index by Kent and Coker (1992): $H' = -\sum_{i=1}^s p_i \ln(p_i)$

Where:

H' = Shannon-Weiner diversity index

S = Total number of species in the community

Pi = Proportion of S made up of the ith species

Ln = natural logarithm

Species Evenness in each community will be determined using Shannon's equitability (E_H):

$$E_H = \frac{H'}{\ln S} = \frac{\sum_{i=1}^s p_i \ln(p_i)}{\ln S}$$

E_H is the Shannon diversity index,

S is the total number of species in the community,

p_i is the proportion of a species to the total number of plants in the

community and

Ln is the natural logarithm.

Sorensen's Species Similarity Index (SI) of Nath et al., (2005) was used to compare diversity across the three ecological zone.

$$SI = \left[\frac{2C}{A+B} \right] \times 100$$

C is the total number of common species;

while A is the number of species in community A

and B is the number of species in community B

Plant Community diversity

The diversity of plant communities was assessed through the multivariate analysis of floristic data. Ordination analysis was carried out using Detrended correspondence analysis (DCA). TWINSpan Software, decotwin 2012, (performs two-way indicator species analysis) version 1.2 (Hill 2012).

Result

Floristic and stand characteristics of riparian forests throughout Omo

Twenty-nine (29) tree species (39%) occurred repeatedly along the riparian systems (major rivers and stream). These included *Diospyros dendo*, *Drypetes sp.*, *Cleistopholis patens*, *Strombosia postulata*, *Macaranga barteri*, *Musanga cecropioides*, *Alstonia boonei*, *Grewia pubescens*, *Bombax buonopozense*, *Margaritaria discoidea*, *Pycnanthus angolensis*, *Sterculia rhinopetala*, *Celtis zenkeri*, *Homalium aylmeri*, *Blighia sapida*, *Elaeis guineensis*, *Terminalia superba*, *Funtumia elastica*, *Ricinodendron heudelotii*, *Ficus exasperata*, *Lecaniodiscus cupanioides*, *Nesodogornia papaverifera*, *Bosqueia angolensis*, *Rauvolfia vomitoria*, *Spondias mombin*, *Dialium guineense*, *Sterculia tragacantha*, *Pavetta corymbosa*, *Dillenia indica*. Also Twenty one (21) tree species were strictly found only along the major rivers, while twenty three (23) species occurred only along the stream. *Diospyros dendo* had the highest total occurrence in the 60 plots surveyed from the riparian system while *Pterocarpus osun* had the least occurrence (1) within the riparian systems

Table 1 shows that the highest total dbh was found in *Diospyros dendo* (2918 cm), *Drypetes species* (2384 cm) and *Cleistopholis patens* (2372 cm) while the lower total dbh was found in *Trichillia gilgiana* (33.9 cm), *Aningeria robusta* (27 cm), and *Pterocarpus osun* (17 cm). Importance value index (IVI) was highest in *Diospyros dendo* (26.90) followed by *Drypetes sp.* (19.68) and *Cleistopholis patens* (16.22) while it was lowest in *Aningeria robusta* (0.417), *Carica Papaya* (0.446) and *Cola acuminata* (0.461) Basal area per hectare was highest in *Zanthoxylum zanthoxyloides* (4.918), *Strombosia postulata* (4.025) and *Cola nitida* (3.693) and low in *Scotellia coriacea* (0.843), *Diospyros soubreana* (0.775), *Annonidium manni* (0.156). The total basal area per hectare of all tree species was 164.68 cm³ with a total volume of 2116.3 m³ per hectare.

Table 1
Tree Species Richness in Riparian Zones of Omo Biosphere Reserve

SPECIES NAME	Total occu	Freq.	T dbh(cm)	M dbh(cm)	density	Dominance	R. Freq	R.den	R. Dom	IVI	BA/ha (cm ³ /ha)	Volume (m ³ /ha)
<i>Afzelia africana</i>	7	5	71	25.6	0.011	0.0013	0.577	0.400	0.190	1.167	1.6	18.9
<i>Albizia auxilary</i>	3	3	64	28.2	0.005	0.0011	0.346	0.171	0.171	0.689	1.762	18.41
<i>Albizia ferruginea</i>	13	5	254.1	30.2	0.021	0.0045	0.577	0.743	0.680	2.000	1.887	24.52
<i>Albizia zygia</i>	4	4	101	28.8	0.006	0.0018	0.461	0.228	0.270	0.960	1.8	20.43
<i>Alstonia boonei</i>	35	22	895.6	28.4	0.056	0.0159	2.540	2.001	2.396	6.938	1.775	30.09
<i>Amphimas tetracoides</i>	3	3	64.2	31.5	0.005	0.0011	0.346	0.171	0.17	0.689	1.968	18.43
<i>Aningeria robusta</i>	2	2	27	33.1	0.003	0.0005	0.230	0.114	0.072	0.417	2.068	14.59
<i>Annonidium manni</i>	30	16	271.6	2.5	0.048	0.0048	1.847	1.715	0.726	4.289	0.156	24.81
<i>Anthocleista djalensis</i>	10	7	439.3	37.8	0.016	0.0078	0.808	0.571	1.17	2.55	2.365	26.94
<i>Anthocleista vogelii</i>	52	9	1270	23.7	0.083	0.0226	1.039	2.973	3.397	7.410	1.481	31.64
<i>Anthonotha macrophylla</i>	5	3	91	22.3	0.008	0.0016	0.346	0.285	0.243	0.875	1.393	19.97
<i>Artocarpus communis</i>	11	7	113.8	29.3	0.018	0.002	0.808	0.628	0.304	1.741	1.831	20.69
<i>Bambusa vulgaris</i>	7	6	1139	22.8	0.011	0.0202	0.692	0.400	3.047	4.146	1.425	31.16
<i>Baphia nitida</i>	6	5	85	21.5	0.01	0.0015	0.577	0.343	0.227	1.147	1.343	19.67
<i>Blighia sapida</i>	23	20	570.1	23.6	0.037	0.0101	2.309	1.315	1.525	5.150	1.475	28.1
<i>Blighia unijigata</i>	3	3	48	19	0.005	0.0009	0.346	0.171	0.128	0.646	1.187	17.4
<i>Bombax buonopozene</i>	27	14	443.6	18.2	0.043	0.0079	1.616	1.543	1.187	4.347	1.137	26.98
<i>Bosqueia angolensis</i>	7	5	193.6	22.2	0.011	0.0034	0.577	0.400	0.518	1.495	1.387	23.31
<i>Brachystegia eurycoma</i>	14	5	355.5	37.8	0.022	0.0063	0.577	0.800	0.951	2.329	2.362	26
<i>Bridelia ferruginea</i>	15	12	315	24.5	0.024	0.0056	1.385	0.8576	0.842	3.086	1.531	24.47
<i>Carica papaya</i>	2	2	38	17	0.003	0.0007	0.230	0.114	0.101	0.446	1.062	16.1
<i>Cassia saimea</i>	38	5	1088	19.7	0.061	0.0193	0.577	2.17	2.91	5.661	1.231	30.96
<i>Ceiba pentandra</i>	6	6	68.5	21.1	0.01	0.0012	0.692	0.343	0.183	1.219	1.318	18.71
<i>Celtis zenkeri</i>	39	27	613.3	23.6	0.062	0.0109	3.117	2.229	1.641	6.988	1.475	28.42
<i>Chrysophyllum albidum</i>	4	4	57	32.5	0.006	0.001	0.461	0.228	0.152	0.843	2.031	17.9
<i>Cleistopholis patens</i>	92	40	2373	26.5	0.147	0.0422	4.618	5.260	6.350	16.229	1.656	34.41
<i>Cola acuminata</i>	2	2	43.6	21.5	0.003	0.0008	0.230	0.114	0.116	0.461	1.343	16.71
<i>Cola nitida</i>	10	7	107	59.1	0.016	0.0019	0.808	0.571	0.28	1.666	3.693	20.69
<i>Corynante pachycercus</i>	3	3	320.6	48.5	0.005	0.0057	0.346	0.171	0.857	1.375	3.031	25.55
<i>Dialium guineense</i>	11	10	117.8	27.2	0.018	0.0021	1.154	0.628	0.315	2.098	1.7	21.11
<i>Dillenia indica</i>	2	2	62.7	29.4	0.003	0.0011	0.230	0.114	0.167	0.513	1.837	18.32
<i>Diospyros dendo</i>	233	50	2918	33.6	0.373	0.0519	5.773	13.3	7.809	26.90	2.1	35.32
<i>Diospyros melistoformis</i>	6	2	39.5	22.4	0.01	0.0007	0.230	0.343	0.105	0.679	1.4	16.28

SPECIES NAME	Total occu	Freq.	T dbh(cm)	M dbh(cm)	density	Dominance	R. Freq	R.den	R. Dom	IVI	BA/ha (cm ³ /ha)	Volume (m ³ /ha)
<i>Diospyros soubreana</i>	6	3	58	12.4	0.01	0.001	0.346	0.343	0.155	0.844	0.775	17.98
<i>Diospyros undebunda</i>	1	1	32	32	0.002	0.0006	0.115	0.057	0.085	0.258	2	15.34
<i>Drypetes sp.</i>	154	39	2384	14.6	0.246	0.0424	4.503	8.805	6.379	19.68	0.912	34.43
<i>Elaeis guineensis</i>	37	16	1080	48.7	0.059	0.0192	1.847	2.115	2.888	6.851	3.043	30.92
<i>Ficus exasperata</i>	18	13	520.2	27.5	0.029	0.0092	1.501	1.02	1.392	3.922	1.718	27.69
<i>Ficus macrophylla</i>	26	8	726	22.6	0.042	0.0129	0.923	1.486	1.942	4.353	1.412	29.17
<i>Funtumia africana</i>	5	3	199	23.6	0.008	0.0035	0.346	0.285	0.532	1.164	1.475	23.44
<i>Funtumia elastica</i>	30	22	343.1	43.9	0.048	0.0061	2.540	1.715	0.918	5.173	2.745	25.85
<i>Garcinia kola</i>	7	6	92	21.2	0.011	0.0016	0.692	0.400	0.246	1.339	1.325	20.02
<i>Gmelina arborea</i>	22	10	581.3	17	0.035	0.0103	1.154	1.257	1.555	3.968	1.062	28.18
<i>Grewia pubescens</i>	28	12	719.8	16.9	0.045	0.0128	1.385	1.600	1.926	4.912	1.056	29.13
<i>Harungana madagascariensis</i>	7	5	169.9	16.9	0.011	0.003	0.577	0.400	0.454	1.432	1.056	22.74
<i>Hexalobus crispiflorus</i>	11	3	398.2	28.4	0.018	0.0071	0.346	0.628	1.06	2.041	1.775	26.51
<i>Hildegardia barteri</i>	3	3	78	28	0.005	0.0014	0.346	0.171	0.208	0.726	1.75	19.29
<i>Holarrhena floribunda</i>	6	5	89.5	36.9	0.01	0.0016	0.577	0.343	0.239	1.159	2.306	19.9
<i>Homalium aylmeri</i>	20	15	977.3	21.1	0.032	0.0174	1.732	1.143	2.615	5.491	1.318	30.48
<i>irvingia gabonensis</i>	5	5	118.3	28.5	0.008	0.0021	0.577	0.285	0.316	1.179	1.781	21.13
<i>Lecaniodiscus cupanioides</i>	18	16	268.1	26.5	0.029	0.0048	1.847	1.02	0.71	3.594	1.656	24.75
<i>Lonchocarpus ciliata</i>	3	2	211.8	28.4	0.005	0.0038	0.230	0.171	0.566	0.969	1.775	23.71
<i>Lonchocarpus cyanescens</i>	3	3	29.3	27.7	0.005	0.0005	0.346	0.171	0.078	0.596	1.731	14.95
<i>Macaranga barteri</i>	38	12	1493	38.9	0.061	0.0265	1.385	2.17	3.996	7.554	2.431	32.36
<i>Maesobotrya barteri</i>	9	6	140	37.4	0.014	0.0025	0.692	0.51	0.374	1.582	2.337	21.88
<i>Margaritaria discoidea</i>	34	22	661.2	31.7	0.054	0.0118	2.540	1.943	1.769	6.253	1.981	28.75
<i>Melacantha alnifolia</i>	3	1	173.8	27.6	0.005	0.0031	0.115	0.171	0.465	0.752	1.725	22.84
<i>Milicia excelsa</i>	2	2	84	46	0.003	0.0015	0.230	0.114	0.224	0.570	2.875	19.62
<i>Millettia thoningii</i>	3	3	56.4	39.1	0.005	0.001	0.346	0.171	0.150	0.668	2.443	17.85
<i>Mitragyna ciliata</i>	10	3	102	19.5	0.016	0.0018	0.346	0.571	0.272	1.191	1.218	20.48
<i>Monodora tenuifolia</i>	7	4	185.5	57.2	0.011	0.0033	0.461	0.400	0.496	1.358	3.575	23.12
<i>Musanga cecropioides</i>	36	22	892.2	21.4	0.058	0.0159	2.540	2.058	2.387	6.986	1.337	17.66
<i>Nauclea diderrichii</i>	17	9	390.6	18.8	0.027	0.0069	1.039	0.971	1.045	3.056	1.175	30.08
<i>Nesodogonia papaverifera</i>	41	22	388	17	0.066	0.0069	2.540	2.344	1.038	5.922	1.062	26.42
<i>Nothospondia staudtii</i>	6	2	199.5	21.7	0.01	0.0035	0.230	0.343	0.533	1.107	1.356	23.45

SPECIES NAME	Total occu	Freq.	T dbh(cm)	M dbh(cm)	density	Dominance	R. Freq	R.den	R. Dom	IVI	BA/ha (cm ³ /ha)	Volume (m ³ /ha)
<i>Pavetta corymbosa</i>	3	3	66.8	27.7	0.005	0.0012	0.346	0.171	0.178	0.696	1.731	18.6
<i>Picralima nitida</i>	34	12	1080	25.8	0.054	0.0192	1.385	1.943	2.88	6.218	1.612	30.92
<i>Piptadeniastum africana</i>	3	3	63.8	24	0.005	0.0011	0.34	0.172	0.170	0.688	1.5	18.4
<i>Pterocarpus osun</i>	4	4	17	30.5	0.006	0.0003	0.461	0.228	0.045	0.736	1.906	12.54
<i>Pterocarpus santalinoides</i>	9	3	304	36.8	0.014	0.0054	0.346	0.51	0.813	1.674	2.3	25.31
<i>Pycnanthus angolensis</i>	28	21	810.4	32	0.045	0.0144	2.424	1.600	2.168	6.194	2	29.65
<i>Rauvolfia vomitoria</i>	9	5	135.8	44	0.014	0.0024	0.577	0.51	0.363	1.45	2.75	21.74
<i>Ricinodendron heudelotii</i>	24	22	995.1	26.7	0.038	0.0177	2.540	1.372	2.66	6.575	1.668	30.56
<i>Rinorea dentate</i>	4	2	112	39.4	0.006	0.002	0.230	0.228	0.299	0.75	2.462	20.89
<i>Rothmania hispida</i>	2	2	44	17.9	0.003	0.0008	0.23	0.114	0.117	0.463	1.118	16.75
<i>Scotellia coricea</i>	31	13	82.6	13.5	0.05	0.0015	1.501	1.772	0.221	3.494	0.843	19.54
<i>Spondias mombin</i>	5	5	154	19	0.008	0.0027	0.577	0.285	0.41	1.275	1.187	22.3
<i>Sterculia oblonga</i>	2	2	107	43.4	0.003	0.0019	0.230	0.114	0.28	0.631	2.712	20.69
<i>Sterculia rhinopetala</i>	36	25	742.3	33.2	0.058	0.0132	2.886	2.058	1.986	6.931	2.075	29.26
<i>Sterculia tragacantha</i>	4	3	137.7	21.4	0.006	0.0024	0.346	0.228	0.368	0.943	1.335	21.81
<i>Strombosia pustulata</i>	85	41	1682	64.4	0.136	0.0299	4.734	4.85	4.501	14.09	4.025	32.89
<i>Terminalia superba</i>	35	17	731.9	53.5	0.056	0.013	1.96	2.001	1.958	5.922	3.343	29.2
<i>Tetrapleura tetraptera</i>	2	22	73.9	16.6	0.003	0.0013	2.540	0.114	0.197	2.852	1.03	19.05
<i>Theobroma cacao</i>	38	15	50.8	31.2	0.061	0.0009	1.732	2.17	0.135	4.040	1.95	17.39
<i>Trema orientalis</i>	2	2	76.5	40.1	0.003	0.0014	0.230	0.114	0.204	0.5500	2.506	19.2
<i>Trichilia gilgiana</i>	3	3	33.9	26.7	0.005	0.0006	0.346	0.171	0.090	0.608	1.668	15.6
<i>Trichilia monadelpha</i>	31	14	703.4	32.1	0.05	0.0125	1.616	1.772	1.882	5.271	2.006	29.03
<i>Uapaca heudelotii</i>	7	6	237	35.1	0.011	0.0042	0.692	0.400	0.634	1.727	2.193	24.21
<i>Zanthoxylum zanthoxyloides</i>	5	5	375	78.7	0.008	0.0067	0.577	0.285	1.003	1.866	4.918	26.24
90	1749	866			2.798	0.6643	100	100	100	300	164.68	2116.3

In all, 74 tree species (dbh $\geq$ 10) from 31 families and 65 genera were recorded along major rivers and streams. Tree species with the highest abundance are *Diospyros dendo*, *Drypetes specie*, *Cleistopholis patens*, *Strombosia pustulata*, *Macaranga barteri*, *Cassia siamea*, *Picralima nitida*, *Musanga cecropioides*, and *Trichilia monadelpha*. The 10 most important species had about half (48.5%) of the total percentage while remaining 64 tree species had 51.49%. Though the 10 most important species had a very low portion (10.74%) of the total basal area, the remaining 64 tree species had a larger percentage of the total basal area (89.26%) in Table 2.

Table 2
Floristic and Stand Characteristics of Riparian Forest in Omo Biosphere Reserve

Riparian forest tree species dominance: number of individuals and basal area 10 most important species					
SPECIES	Absolute Abundance	Relative Abundance (%)	Total dbh (cm)	BA (m ²)	Relative Basal Area (%)
<i>Diospyros dendo</i>	120	20.58	2918	669.01	28.25
<i>Drypetes sp.</i>	106	18.18	2384.1	446.55	18.86
<i>Cleistopholis patens</i>	88	15.09	2372.8	442.07	18.67
<i>Anthocleista vogelii</i>	52	8.91	1269.7	126.52	5.34
<i>Strombosia postulata</i>	45	7.71	1682.1	222.28	9.38
<i>Macaranga barteri</i>	38	6.51	1493.4	175.13	7.39
<i>Cassia siamea</i>	38	6.51	1088	93.00	3.92
<i>Picralima nitida</i>	34	5.83	1079.6	91.47	3.86
<i>Musanga cecropioides</i>	31	5.31	892.2	62.51	2.64
<i>Trichilia monadelpha</i>	31	5.31	703.4	38.83	1.64
Total of the 10 most important tree species	583	48.50	15883.3	2367.4	10.74
Total of the remaining 64 tree species	619	51.49	20302.7	19675.5	89.26
Overall total of the 74 tree species	1202	100	36186.0	22042.9	100

Table 3 shows the Shannon index of trees varies from 2.17 to 3.036 through the major rivers and streams in the core, buffer and transition zones. Riparian forests trees along streams had higher diversity (3.486), followed by the major rivers (3.395) and uplands (3.253). The overall riparian forest tree diversity was 3.743 the Equitability index of Pielou was 0.562. Sorenson similarity index for riparian system and upland in the core, buffer, and transition are 36.7%, 26.9% and 30% respectively. The overall Sorenson index for all riparian system and upland plots is 90%

Table 3
Diversity of tree species in the riparian systems of Omo Biosphere Reserve

Region	Site	No of species	Abundance N	Shannon DiversityH ⁺	Evenness E	Margalef Simpson Index		Fisher alpha	Sorensens index %
CORE	Major river	26	267	2.773	0.615	4.304	0.906	6.78	36.7
	Stream	24	182	2.895	0.753	4.25	0.924	7.051	
	Upland	24	227	2.467	0.491	4.079	0.832	6.469	
	Major river	25	173	2.757	0.629	4.473	0.905	7.603	
BUFFER	Stream	33	221	3.036	0.631	6.647	0.995	15.57	26.9
	Upland	28	230	2.82	0.598	4.793	0.907	7.983	
	Major river	27	137	3.14	0.859	5.178	0.949	9.984	30
TRANSITION	Stream	14	209	2.17	0.626	2.250	0.847	3.078	30
	Upland	18	90	2.3	0.554	3.62	0.818	6.473	
All region	UPLANDS	54	548	3.253	0.479	11.67	0.9582	19.61	
All region	MAJOR RIVERS	53	583	3.395	0.561	8.037	0.9418	13.92	90.5
	STREAMS	52	619	3.486	0.616	7.792	0.9558	13.23	
Riparian Forest of Omo	All major rivers and streams	75	1202	3.743	0.562	10.3	0.9625	17.44	

Figure 2 represents the cluster analysis (Jaccard) showing the similarity in relationship within the 60 plots of major rivers and streams in the core, buffer and Transition zones. There are two major groups relating at 5%, In the first group, plots in the stream of the transition zone (STP8 and STP5) showing the highest similarity at 100% and in the second group, plots in the major river and streams of the core and buffer showed more similarities (MBP6 and SCP6; MBP2 and SCP2) both relating at 100% .

Figure 3 shows the three plant communities in accordance with the cluster shown in Fig. 2 The first community represents the **Community of** *Cleistopholis patens* and *Anthocleista vogelii* as a result of their maximum abundance in the community. These species are found strictly along riparian forests of the

Stream and are also restricted mainly to the buffer and transition zones. They were found mainly in the following plots; SBP 1, SBP 2, SBP 6, SBP 10, SBP 5, SBP 9, STP 1, STP 9, STP 2, STP 6, STP 8, STP 7, STP 10, STP 4, STP 8, and STP 5. The Second community represents the **Community of** *Diospyros dendo* and *Drypetes* species. These species were found in both **major rivers and streams** and are also restricted to the core and buffer zones. They are found mainly in the following plots SBP 3, SBP 7 SBP 4, SBP 8, MBP 5, SCP 5, MBP 1, MBP 10, SCP 1, MBP 3, SCP 9, MBP 6, MBP 9, MBP 4, SCP 4, MBP 7, SCP 7, SCP 8, MCP 8, MCP 1, MBP 1, SCP2, MBP 8, SCP 10, SCP 6, MCP 6, MCP 10, MCP 4, MCP 5, MCP 2, MCP 3, MCP 7, MCP 9. The third community is the **Community of** *Azelaia africana*. These species are found mostly in the **Major rivers** and are restricted to the **transition zones**. They were found in plots MTP 1, MTP 2, MTP 9, MTP 4, MTP 6, MTP 7, MTP 10, MTP 5, MTP 8.

Discussion

This study revealed the assessment of variations in the tree species composition of the riparian forest vegetation of Omo Biosphere Reserve, Nigeria. Seventy-Four tree species from 31 families and 65 genera encountered in the riparian systems of Omo Biosphere Reserve is relatively high in area cover when compared with 224 species from 120 families recorded in riparian forest flora of the whole of Benin Republic (Natta 2003). The composition and plant community structure are affected by the range of disorders at different levels, frequencies and extent of human activities that reduce species diversity. (Vallari et al. 2009).

Species along the stream had higher abundance than those along Major Rivers, which may be as a result of the low intensity in the rate of flow of water which enables inundation and support of seed settlement for germination. Generally, biodiversity in natural riparian areas is sustained by high spatial and temporal variability in the environmental conditions reflecting strong environmental gradient that exists at different scales (Ward et al. 2002).

Many tree species typical of riparian forest which include *Diospyros dendo*, *Drypetes sp.*, *Cleistopholis patens*, *Strombosia postulata*, *Macaranga barteri*, *Musanga cecropioides*, *Alstonia boonei*, *Grewia pubescens* are dominant and characteristic of Riparian forest along Mayo Kam of Gashaka, Taraba State. Nigeria (Mubi 2012). *Diospyros dendo* was found to be the most abundant tree species in the riparian zones of the forest reserve. A similar result was observed by (Ojo 2004) on the fate of a tropical rainforest in Nigeria, the Abeku sector of Omo Forest Reserve. While *Pterocarpus osun* was the least abundant species, it is a specie mostly found in the savanna ecosystem, riparian forests often combine plants from various ecosystems. This is similar to the result from northern Australia, where riparian strips contain vegetation dominated by diverse floristic elements unrelated to monsoon rain forests (Woinarski et al. 2000). Many common species are found in the riparian systems to be encroachments of upland forests. For example, *Elaeis guineensis* is a pioneer species and it is heliophytic common to all Central and West Africa. (Chepstow-Lusty et al. 2001).

The Core zone of the reserve has the highest occurrence of riparian and upland tree species in comparison with the buffer and transition zones. This is as a result of the undisturbed nature of the forest as the strict nature reserve (SNR) where manipulative research is banned, consisting of firmly secured ecosystem that contributes to the conservation of landscapes, ecosystems, species and genetic variation. This could be attributed to little or no human interference on the natural forest. Deforestation and other anthropogenic activities have important implications on forest structure, species diversity, healthy watershed ecosystems and the sustainability of livelihoods. (Alcott et al. 2013); and (Steffen et al. 2015). *Diospyros dendo* is the most occurring species in the core zone and more species were found along major rivers.

In the buffer zone, tree species along the stream had higher representation, the most occurring species is the *Cleistopholis patens* that is commonly found in disturbed riverine and swamp forest. It has a potential for use as a pioneer to restore woodland. In Sierra Leone, 7-year-old *Cleistopholis patens* trees reached 13 m tall and over 20 cm in bole diameter, and in Ghana the same height and diameter have been reached on 4-year-old logging tracks. In Guinea, it has been reported to start fruiting already at 5 years after planting. In Cote d'Ivoire and Ghana, ripe fruits occur in August-November. In Uganda, rotten material of dead *Cleistopholis patens* trees is an important food for chimpanzees; they chew it, extracting the juice. Hence, the presence of *Cleistopholis patens* in Omo biosphere reserve depicts its ability to enhance restoration in the ecosystem. Its invasive nature in disturbed forest and rapid growth seem to offer good possibilities for commercial timber production. Research has confirmed several of its applications in traditional medicine e.g. antimicrobial, anthelmintic and antimalarial activities, which may offer opportunities for drug development (Atuhe 2010).

In the transition zone, higher diversity was found in species along the major rivers. *Theobroma cacao* had the highest occurrence. This is as a result of the intense farming activities of the inhabitants who earned their living from the sales of this economic tree produce. Riverine landscapes are essentially heterogeneous, dynamic, biologically and spatially complex (Ward et al. 2002) and contribute to the diversity and function of both terrestrial and aquatic ecosystem. (Acker et al. 2003).

The DCA results tend to strengthen the cluster analysis results, the ordination of the 60 study plots of the riparian zone forms three groups comprising community of *Cleistopholis patens*, community of *Diospyros dendo* and *Drypetes sp.* And community of *Azelaia Africana*. The community of *Diospyros dendo* represents plots in the Major rivers and Stream which cut across all zones, and the community of *Azelaia Africana* also found in the major rivers but restricted to the transition zones. The high degree of dispersion of the plots inside the DCA diagram indicates the floristic heterogeneity of the forest. Ecologically, most of the species recorded in the groups of the studied rainforests are typical elements of most rainforest. Natta A. K. 2000, found that importance of waterways-riparian forest along streams and along rivers, relief, topography, latitude and environmental gradient that partitioned the riparian forest of plant communities of Republic of Benin. In this analysis, species frequently show marked preferences for specific environmental conditions and plant communities identified follow regional differences. Generally, geographical isolation is the main source of variation, which contributes to the variation in physical factors between the communities of forest.

Conclusion

Riparian forests are among the most vulnerable forest formations in all regions, yet of high ecological importance. Their high species richness on relatively small areas (patches and narrow corridors) makes them special and unique sites. At this stage of the investigation on Omo riparian forest diversity, we can say that 9.84% of Omo's total forest area of 813.20 sq. km harbours a riparian vegetation of 80.04 sq. km. Their numerous species are either rare, for example *Cleistopholis patens* or with superior adaptability to a specific habitat. This portrays them as a habitat for endemic plant species and subsequently a vital ecosystem for numerous wild and birdlife species.

Riparian ecosystems are essential multifunctional elements of the worldwide ecological network, their preservation in Omo is of utmost importance with the threat of a rapid increase in human occupation of land and possible change in climate.

Declarations

Funding/Competing interest

No funding was received for conducting this study and for the preparation of this manuscript, All authors certify that have no affiliations with or involvement in any organization or entity with any organization or entity with any financial interest or non-financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

References

1. Acker AS, Lienkaemper G, McKee WA, Swanson FJ, Miller SD (2003) Composition, complexity, and tree mortality in riparian forests in the central Western Cascades of Oregon. For Ecol Manag 173:293–308
2. Akendengué B, Champ P, Nzamba J, Roblot F, Loiseau PM, Bories C (2009) Antifungal and anthelmintic activities of *Cleistopholis patens* (Annonaceae). Planta Med 75(10):1143–1145
3. Akinyemi OD (2017) Population and Structure of Trees in Selected Lowland Rainforest Reserves in Southwestern Nigeria. Dissertation, University of Ibadan, Nigeria
4. Amadi CN, Odigie JO, Siminialayi IM (2009) The effects of methanol extracts of *Cleistopholis patens* on the reproductive system of female Wistar rats. Asian Pac J Trop Med 2(1):6–12
5. Alcott E, Ashton M, Gentry B (2013) Natural and Engineered Solutions for Drinking Water Supplies: Lessons from the Northeastern United States and Directions for Global Watershed Management. CRC Press, Boca Raton, FL. Accessed on 23 July 2001
6. Atuhe G (2010) The ecological status of *Cleistopholis patens* in Budongo Forest Reserve, Uganda. A summary of the major findings. [Internet] Budongo Conservation Field Station. <http://culture.stand.ac.uk/bcfs/documents/reports/Ecological%20status%20of%20CP%20in%20BFR.pdf>. Accessed September 2011
7. Boyom FF, Ngouana V, Kemgne EAM, Zollo PHA, Menut C, Bessière JM, Gut J, Rosenthal PJ (2011) Antiplasmodial volatile extracts from *Cleistopholis patens* Engl. and Diels and *Uvariastrum pierreanum* Engl. and Diels (Annonaceae) growing in Cameroon. Parasitol Res 108(5):1211–1217
8. Chatzinikolaou Y, Ntemiri K, Zogaris S (2011) River riparian zone assessment using a rapid site-based index in Greece. Fresenius Environ Bull 20:296–302
9. Chepstow-Lusty A, Maley J (2001) *Eleais guineensis* Jacq. (oil palm) fluctuations in central Africa during the late Holocene; climate or human driving forces for pioneering species. Veg history Archaeobotany 10(2):117–120
10. Dahl M, Nilsson B, Langhoff JH, Refsgaard JC (2007) Review of classification systems and new multi-scale typology of groundwater surface water interaction. J Hydrol 344:1–16. 10.1016/j.jhydrol.2007.06.027
11. Fayera SW (2006) Biodiversity and ecology of Afromontane rainforests with wild *Coffea arabica*. Popul Ethiopia: Ecol Dev Ser No 38:144
12. Haddad NM, Brudvig LA, Clobert J, Davies KF, Gonzalez A, Holt RD, Lovejoy TE, Sexton JO, Austin MP, Collins CD, Cook WM, Damschen EI, Ewers RM, Foster BL, Jenkins CN, King AJ, Laurance WF, Levey DJ, Margules CR, Melbourne BA, Nicholls AO, Orrock JL, Song DX, Townshend JR (2015) Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci Adv 1:e1500052
13. Lovett S, Price P (2007) Principles for riparian lands management. Land and Water Australia, Canberra
14. Meek CS, Richardson DM, Mucina (2010) A river runs through it: land-use and the composition of vegetation along a riparian corridor in the Cape Floristic Region, South Africa. Biol Conserv 143:156–164
15. Mubi AM (2012) Species distribution within Riparian Landscape along Mayo Kam of Ghashaka. Taraba State, Nigeria. *Ethiopian Journal of Environmental Studies and Management* Vol. 5 No.1 2012
16. Natta AK (2000) Tree species diversity assessment in riparian forests using remote sensing, geographical information systems and geostatistics (case study of Toui-Kilibo protected forest in Benin). MSc thesis, ITC Forest Science Division, Enschede, The Netherlands. 91p
17. Natta AK (2003) Ecological assessment of riparian forests in Benin: Phytodiversity, Phytosociology and spatial distribution of tree species, vol ISBN 90–5808–954–1. Wageningen University. Published Ph.D. Thesis
18. Ojo LO (2004) The fate of a tropical rainforest in Nigeria: Abeku sector of Omo Forest Reserve. Global Nest 6(2):116–130
19. Perry LG, Andersen DC, Reynolds LV, Nelson SM, Shafroth DC (2012) Vulnerability of riparian ecosystems to elevated CO₂ and climate change in arid and semiarid western North America. Glob Change Biol 18:821–842
20. Sonké B, Lejoly J (1998) Biodiversity study in Dja fauna reserve (Cameroon): using the transect method. In: Huxley CR, Lock JM, Cutler DF (eds) *Chorology, Taxonomy and Ecology of the Floras of Africa and Madagascar*. Royal Botanic Gardens, Kew, pp 171–179

21. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, Biggs R, Carpenter SR, Vries W, de Wit CA, de Folke C, Gerten D, Heinke J, Mace GM, Persson LM, Ramanathan V, Reyers B, Sörlin S (2015) Planetary boundaries: guiding human development on a changing planet. *Science* 347:1259855. <http://dx.doi.org/10.1126/science.1259855>
22. Tuomisto H, Roukolainen K, Yli-Halla M (2003) Dispersal, environment and floristic variation of western Amazonian Forests. *Science* 299:241–244
23. U.S. EPA (2014) Methods for Evaluating Wetland Condition: Vegetation-Based Indicators of Wetland Nutrient Enrichment. http://www2.epa.gov/sites/production/files/documents/wetlands_16indicators.pdf
24. Accessed (2014) 05 May
25. Vallari LA, Chapin DM, Jones JE (2009) Riparian forest structure and succession in second growth stands of central Cascade Mountains, Washington, USA. *For Ecol Manag* 257: 1375–85
26. Ward JV, Tockner K, Arscott DB, Claret C (2002) Riverine landscape diversity. *Freshw Biol* 47:517–539
27. Woinarski J, Brock CZ, Armstrong M, Hempel C, Cheal D, Brennan K (2000) Bird distribution in riparian vegetation in the extensive natural landscape of Australia's tropical savanna: a broad-scale survey and analysis of a distributional data base. *J Biogeogr* 27:843–868
28. Wu JG, Loucks OL (1995) From balance of nature to hierarchical patch dynamics: a paradigm shift in ecology. *Q Rev Biol* 70:439–466

Figures

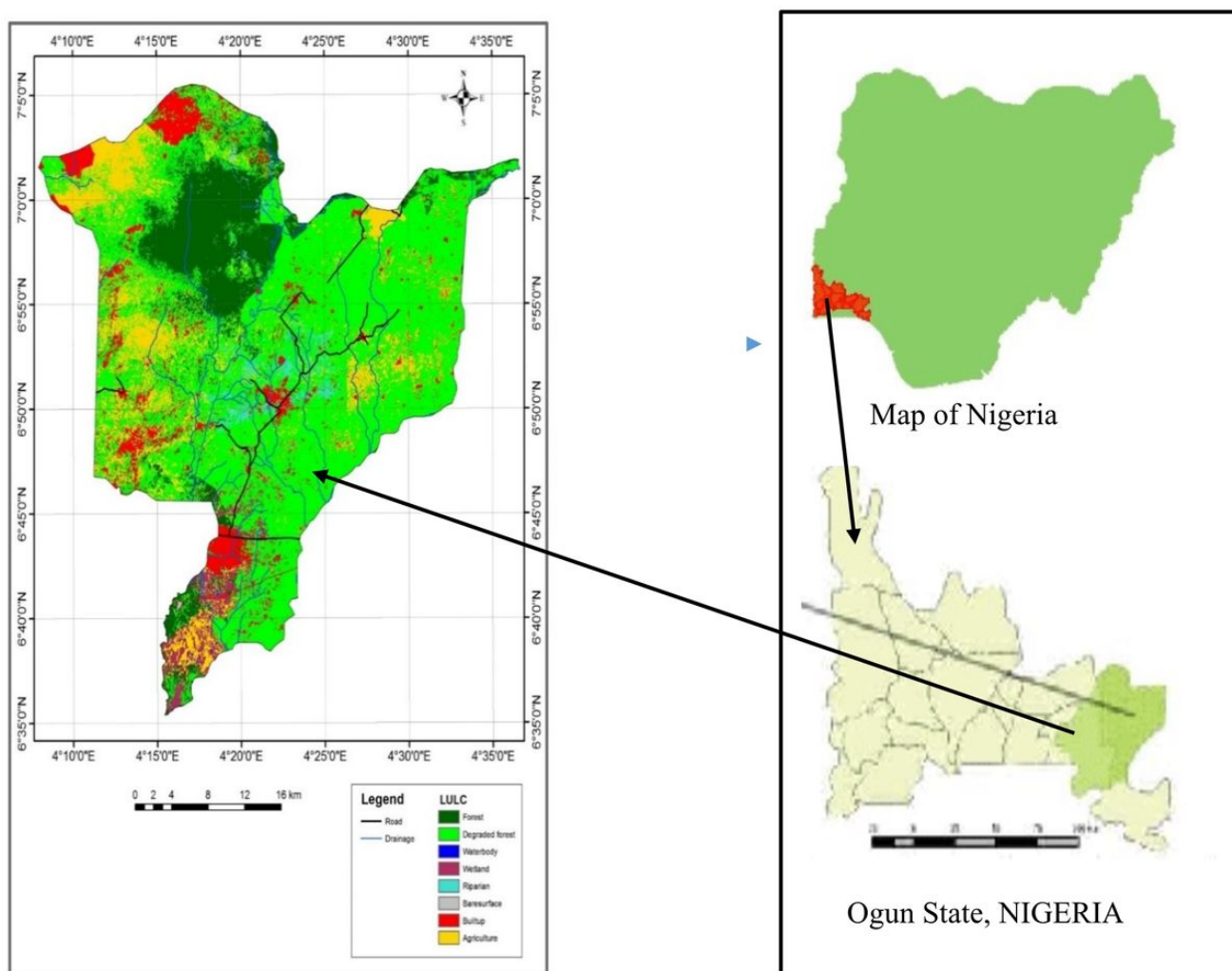


Figure 1

Map of Omo Biosphere Reserve, Ogun State, Nigeria.

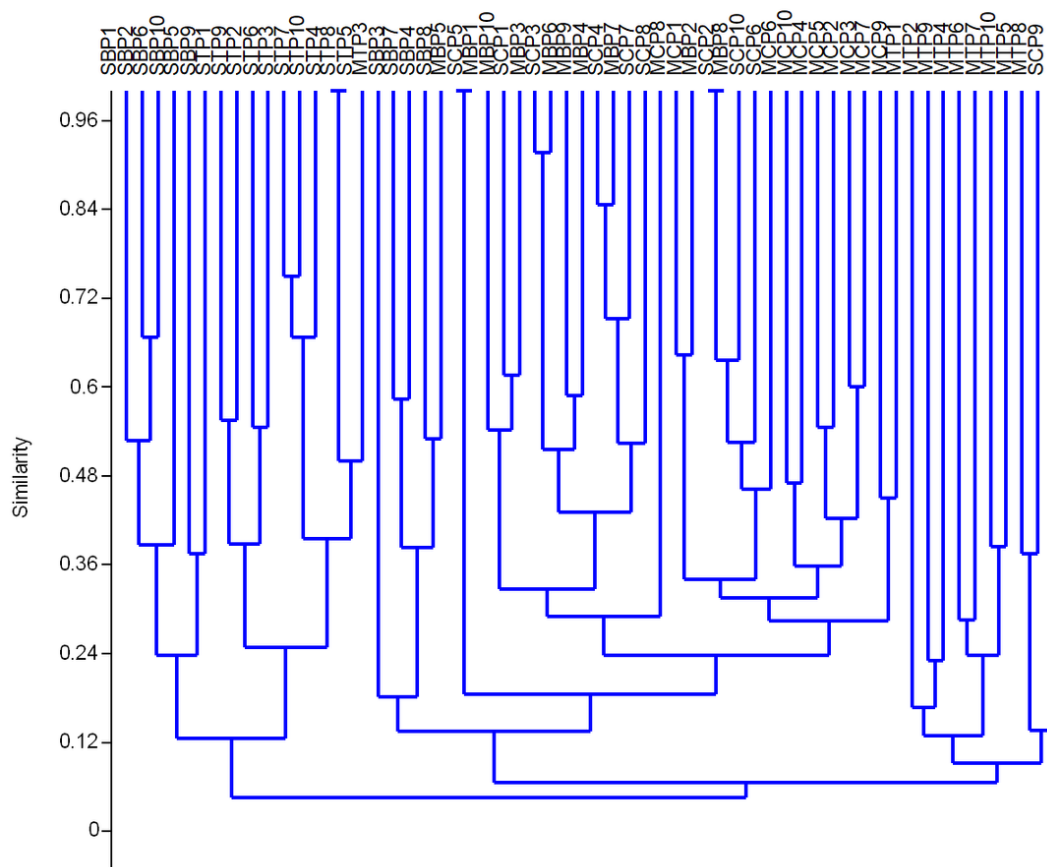


Figure 2

Cluster of the Riparian Zones (Major Rivers and Streams) of Omo Biosphere Reserve

Key: M = MAJOR RIVERS

S = STREAM

C = CORE

B = BUFFER

T = TRANSITION

P = PLOTS (1,2,3,4,5,6,7,8,9,10)

