

AN INVENTORY OF BIODIVERSITY RESOURCES IN SOME VEGETATION PATCHES IN SOKOTO METROPOLIS, SOKOTO STATE

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ABSTRACT

Since 1999 when democracy was reintroduced in Nigeria, the increasing revenue from crude oil export has resulted in tremendous expansion and intensification of land uses in several towns including Sokoto. In Sokoto Metropolis, residential and commercial land uses have largely encroached upon green areas within and at the margin of the town. This study inventoried biodiversity resources in some vegetation patches in the metropolis. Normalized Difference Vegetation Index (NDVI) was computed for the study area after applying image pre-processing and processing standard algorithms to near-anniversary dry season Landsat data of 1984, 1998, 2013 and 2017. Z-scores were calculated for the NDVI images, while each was classified using 1 standard deviation to the mean ($\mu \pm \sigma$) algorithm. A field inventory of both woody and herbaceous vegetation as well as faunal species was subsequently conducted at some selected patches using quadrat samples. An in-depth interview with people living in the neighbourhood of the patches was also conducted. Results show a downward trend in vegetation coverage of the metropolis over the years. Patches A and D are 100% lost, while only 4% and 21% of B and C are left as at 2017. Also, there are 34 woody species belonging to 21 families; and 19 herbaceous species belonging to 20 families. While the Combretaceae family constitute the most abundant woody species, the Gramineae family is the most abundant of the herbaceous species. In the faunal study, the most abundant were invertebrates, followed by vertebrate avian, rodent and reptilian species. Utilitarian product/services provided by vegetation patches include food supplements, feed for livestock, medication, fuel-wood and building materials amongst others. Consequent upon biodiversity resource degradation, it is recommended that the fragmented patches be protected while already destroyed ones should be replicated in the neighbourhood lands.

Keywords: Land use, Green Area, Woody species, Herbaceous species, Fauna

1. Introduction

The British colonial administration (which completed its conquest of Nigeria in 1904) had created two dual communities in northern Nigerian towns in order to preserve the pillars of its indirect rule. Each town had two set-

ups: the first consisted of the indigenous city, later with its associated Tudun Wada suburbs (made up of migrants, mostly Muslim northerners). This was governed by the Native Administration and Ordinances. The second

was the administration in new colonial townships or cantonments, known as sanitary districts. In the latter, bye-laws, ordinances, building regulations and town planning rules were implemented. There were building-free zones separating the later from the former, covered by expanse of wilderness and/or plantations. The rationale for such segregation policy was attributed to health reasons so that 'the Europeans shall not be exposed to the attacks of mosquitoes and be infected with... malaria or yellow fever; also as a safeguard to bush fire... common to native (areas)... during the dry season, and finally to remove inconveniences felt by Europeans whose rest (was) disturbed by drumming and other noises dear to natives' (Sokoto, 2013). Later the building-free zone became a 'non-residential area, then a neutral zone (1921), greenbelt (1953), and finally in 1966, it was abandoned as a device to segregate in an attempt to integrate existing government residential and institutional areas with native towns' (Sokoto, 2013).

Expansion of urban and rural areas has been a reality since Nigeria gained independence in 1960. Petroleum derived income which became dominant in the early 1970s and the associated continual creation of states and local government areas (which constituted, the 2nd and 3rd tiers of government aside from the federal) gave impetus to the urbanisation trend. Each of the 36 states of the federation has a state headquarter around which urbanisation grew. Urban expansion also exploded in the vicinity of the Federal Capital Territory especially from the 1980s, leading to the proliferation of illegal squatter settlements.

The 1999 general elections which ushered in the Third Republic coincided with a phase of rising oil earnings which shot up the national revenue from 9.5 billion naira as at 1999 to over 9 trillion naira in 2013 (Central Bank of Nigeria, 2013). This increased revenue which

became conspicuously manifested in rising urban expansion resulting in encroachment and fragmentation of vegetation patches, left as green spots in and around Nigerian towns. A Nigerian government's White Paper has acknowledged the presence of uncontrolled sort of urban development, occasioned by the violation of planning rules. While the major aim of urban development in Nigeria is to ensure availability of land for the purpose of controlled and orderly development in urban areas, the unregulated nature of such development has been attributed to the difficulty experienced by individuals and organisations in accessing land due to tenurial and institutional bottlenecks (Oruwari and Owei, 2006).

Dantuni (2012) posited that encroachment upon vegetation patches culminating in the violation of the Sokoto Master Plan (1983) in Sokoto Metropolis was as a result of multiple allocation of plots by authorised bodies, involvement of unauthorised agents in land allocation, land use encroachment on service infrastructure, proliferation of unplanned settlements, and unapproved subdivision and re-designation of building plots, among others.

Vegetation patches in the precincts of urban areas are meant to serve green belt functions. Green belts generally refer to tracts of vegetation communities, undeveloped and agricultural land encircling urban areas, where amount of new building is restricted though not completely banned (Mayhew, 2009; Sokoto, 2013). Vegetation patches in vicinity of towns constitute natural habitats for biodiversity resources which through complex interaction with the social and ecological environments produce certain goods and services that make urban environment qualitatively better and more convenient for life. The floral realm plays an important role in making the earth habitable: It maintains air and water quality and moderates the micro-climate. Green plants also produce oxygen

which humans and other animals respire with; they also interact with the physical environment through the photosynthetic process and produce carbohydrates upon which other biotic life depend (whether directly or indirectly) for sustenance (Johnston, 1988; Alonso *et al.*, 2001; Adamu, 2007). Ecosystem services provided by plants include protection of soil loss against wind and water erosion, humus accumulation, nitrogen fixation, and nutrient supply from deeper layers. Moreover, plants stabilise regional and global climate, provides for pollution control and act as carbon sink (Botkin and Keller, 1998; Alonso *et al.*, 2001; Adamu, 2007). Vegetation patches also yield utilitarian products/services such as fuel-wood, nuts vegetable, gum, spices, dyes, medicinal products, fodder for grazing and browsing by wildlife and livestock. They also serve as avenues for recreation while crown of trees and shrubs offer shade (in hot weather) (GFA, 2001; Adamu, 2007). Hence, these environmental and utilitarian services underscore the importance of vegetation patches not only in Sokoto metropolis but in all cities and towns in Nigeria.

The Sokoto Metropolis, according to documentary evidence has a legacy of vegetation patches in the form of green tract projects since colonial times which became incorporated into the Sokoto Master Plan in 1983. These vegetation patches and green tracts covered 420 hectares (ha) as at 1967; by 2002 they had declined to 101.38 ha, and by 2010, they had further reduced to 55.46 ha (Sokoto, 2013). Most studies that dwell on vegetation patches or green belts' depletion and conversion in Sokoto town have concentrated on the extent of encroachment and likely impact on the micro-climate (Sokoto, 2013; Eniolorunda and Abubakar, 2016) or conversion to other land uses due to road idealization (Tukur, 2009). The institution of the green areas was with the

expressed goal of providing facilities for recreation, aesthetics, improvement of environmental quality, and deriving benefits from their utilitarian products (Benna Associates, 1982). However, urbanisation process expressed in terms of expanding land uses including residential, commercial and institutional has led to fragmentation of such vegetation patches, and depletion of its biodiversity, especially since the early 1970s (which marked the beginning of the oil boom years). This process continued and was given impetus at the start of the 21st millennium phase of soaring prices of crude oil which is the major foreign exchange earner in Nigeria. This trend continued to jeopardise the environmental and utilitarian services/products provided by such green landscapes within the city to the chagrin of all concerned. This paper therefore attempts to take an inventory of the plant and animal species on the fragmented patches and determine their utilitarian services/products enjoyed by the people – so as to sensitize and call attention to the need to maintain them for environmental integrity and for the present and future generations.

2. Conceptual Framework

Environmentally Sensitive Area (ESA) and Strong Sustainability Concepts constitute the twin framework for this study. The former denotes a fragile ecosystem where conservation of the natural environment is sustained by state controls and/or grants (Mayhew, 2009), while the latter that is Strong Sustainability Concept falls within the conceptual rubric of sustainable development. It posits that natural capital – the range of functions the natural environment provides for humans and for itself – should be afforded special protection. The Strong Sustainability Concept sees weak interpretation of sustainable development as bound to an anthropogenic world-view, and recommends

maintaining livelihood opportunities by reconciling sound human development and environment integrity. The concept disdains weak interpretation that resorts to authoritative and coercive structures, such as market forces, and advocates more participatory, transparent and democratic processes (Mayhew, 2009). Hence, while government intervention is required to sustain the natural environment in the precincts of cities *ala* ESA concept, that calls for an enabling environment through the realisation and implementation of the requirements of the Strong Sustainability Model.

Specific objectives of this paper include to: map the vegetation and detect changes within the study sites and other parts of the metropolis, determine the species composition and families of woody plants on the vegetation patches, determine the species composition and families of herbaceous plants, explore the availability of vertebrate and invertebrate wildlife and determine their species and families.

3. Materials and Methods

3.1 Study area

Sokoto metropolis is located between longitudes 5.17° and 5.27° E and latitudes 12.98° and 13.09° N (Figure 1), occupying approximately 254.3 square kilometres (Eniolorunda, 2010a). Located in the Sudan savannah (Olayinka, 2003), annual rainfall stands around 600mm while average daily temperature is about 36°C (Odjugo, 2010; Ifabiyi and Eniolorunda, 2012; Umar, 2013). Generally, vegetation is mainly of short and stunted shrubs and grasses around the metropolis, but the inner part and the precincts have vestiges and patches of vegetation composed mainly of trees (Eniolorunda, 2010a). In the north of the metropolis is the Sokoto-Rima river floodplain which prevents the city growth in that direction. This and a number of anthropogenic factors are contributory to land use /land cover changes that impact on the vegetation within the metropolis.

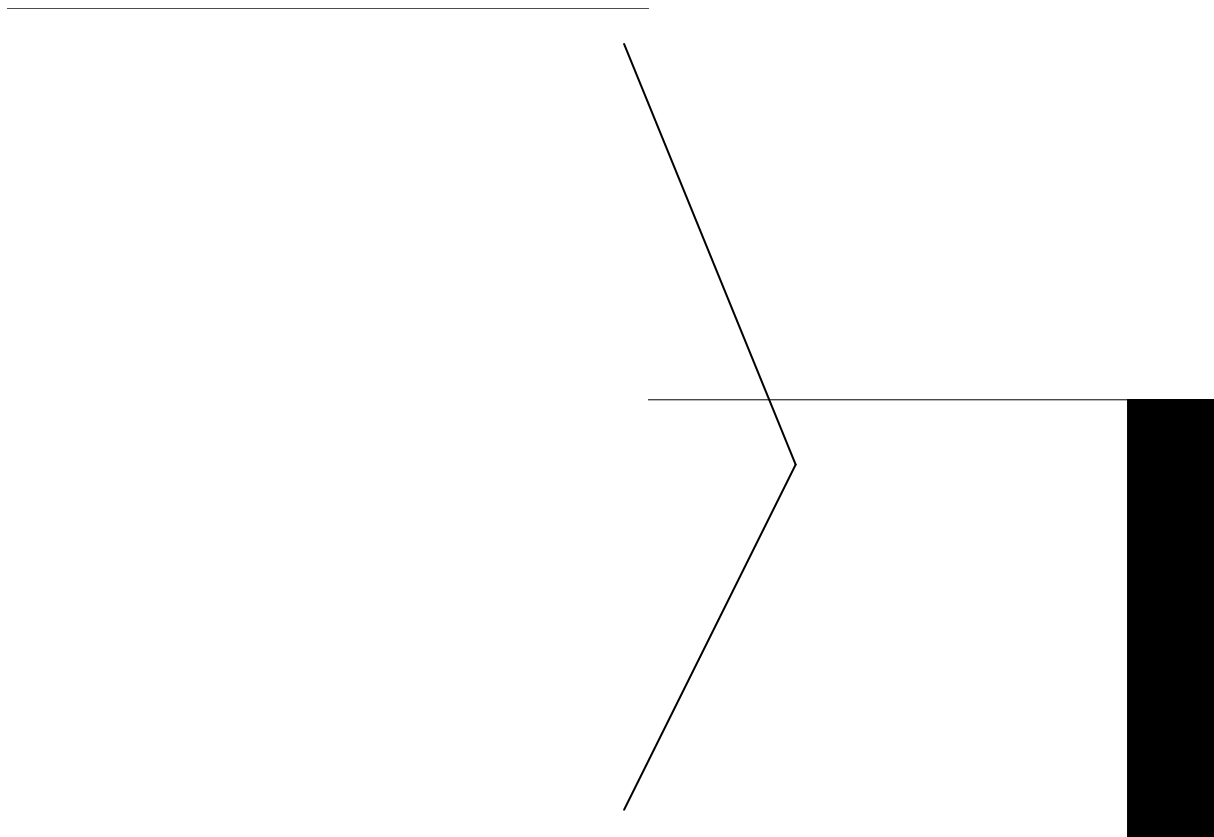


Figure 1: Study Area

3.2 Materials

3.2.1 Image Data

For the first objective, Landsat data collected by Multispectral Scanner (MSS) of 1984 (18-12-1984), Thematic Mapper (TM) of 1998 (23-11-1998) and Operational Land Imager - Thermal Infrared Sensor (OLI-TIRS) of 2013 (02-12-2013) and 2017 (11-01-2017) located in path/row 191/051 of the archive centre of the United States Geological Survey (USGS) were used. These are near-anniversary and dry season images. Surviving dry season vegetation in a semi-arid environment is composed mainly of trees. Thus, the selection of the images at irregular intervals was done to avoid cloudy images. Also, data collected by the Enhanced Thematic Mapper Plus (ETM⁺) were avoided for their Scan-line-Corrector (SLC) - Off problem.

3.2.2 Image Pre-processing

The selected images were cloud free and Level 1T corrected based on their metadata; however, they were all subjected to haze suppression. This was carried out using Dark Object Subtraction (DOS) within the PANCROMA environment. The 1984 was subsampled to a resolution of 30m from 60m for image co-registration and integration with newer Landsat data. This was followed by the sub-mapping of Sokoto metropolis from each of the scenes.

3.2.3 Image Processing

Normalized Difference Vegetation Index (NDVI) was computed with the Red and Near-Infrared (NIR) bands of each image selected using:

$$NDVI = (NIR - RED) / (NIR + RED)$$

where: NIR is the Near Infrared band while RED is the Red band of the Landsat data. For

the Landsat MSS and ETM, bands 3 and 4 are RED and NIR respectively, while bands 4 and 5 are RED and NIR for the OLI-TIRS. NDVI is an index of choice for characterizing vegetation phenology as it is capable of differentiating between vegetated and non-vegetated surfaces (Lunette and Elvidge, 1998; McDonald *et al.*, 1998).

Z-scores were computed for each of the NDVI data, after which it was classified using 1 standard deviation to the mean ($\mu \pm \sigma$) algorithm (Eastman, 2009; Abubakar and Eniolorunda, 2016). Classification is a veritable way of environmental monitoring as it provides information on disasters and anthropogenic changes (Eastman, 2009).

3.2.4 Image Change Detection

The area coverage of each classified NDVI was calculated, and Post Classification Comparison was used to detect vegetation changes from one date to another (Eniolorunda *et al.*, 2016).

3.3 Site Sampling, Field Inventory and Interview

Four vegetation patches which underwent partial or total depletion, mostly located at the fringes of the built-up area, were chosen as sampling locations (Figure 1) Patch A, B, C, and D namely:

- A. Adjacent Rinjin Sambo Roundabout;
- B. At the back of Giginya Secretariat (Western Bypass);
- C. Adjacent Police Headquarters (along Wurno Road);
- D. Close to the Federal Secretariat

For each of the above, both plant and animal assessments were carried out. For samples B, C and D, field assessments were carried out in 2014 to determine the floral and faunal

composition within them. A baseline study was conducted for sample **A** in 2007, and this was followed by a qualitative inquiry with the aid of the local people who helped identify the vernacular (Hausa names), utilitarian products/services and the details of herbaceous species many of which are now dry and turned into litter except along moist spots. The local people also helped to identify and recall wildlife in the vertebrate and invertebrate categories which either utilise such patches as habitats or come there daily, occasionally or seasonally for sustenance and/or rest.

A total of 12 sampling points were randomly selected across the vegetation patches; each patch being allocated 3 points. Quadrats of 5m by 5m dimension were used for woody species assessment, while quadrats of 2m by 2m were used for herbaceous species assessment. All plant species contained in the sample quadrats were identified with the help of the local people. Species identification and nomenclature largely followed the outline of Keay (1959), using data from the sample plots. Wildlife study relied on observation and qualitative inquiry depending largely on in-depth interview with the people in the neighbourhood that possess intimate knowledge of the local fauna.

4. Results

4.1 Vegetation Cover and Change Detection

The vegetation patterns of all the years are presented in Figure 2, while Figure 3 shows the Post Classification Comparison (PCC) of the overall vegetation for all the years. Figure 4 also compares the changes in the selected patches over the years.

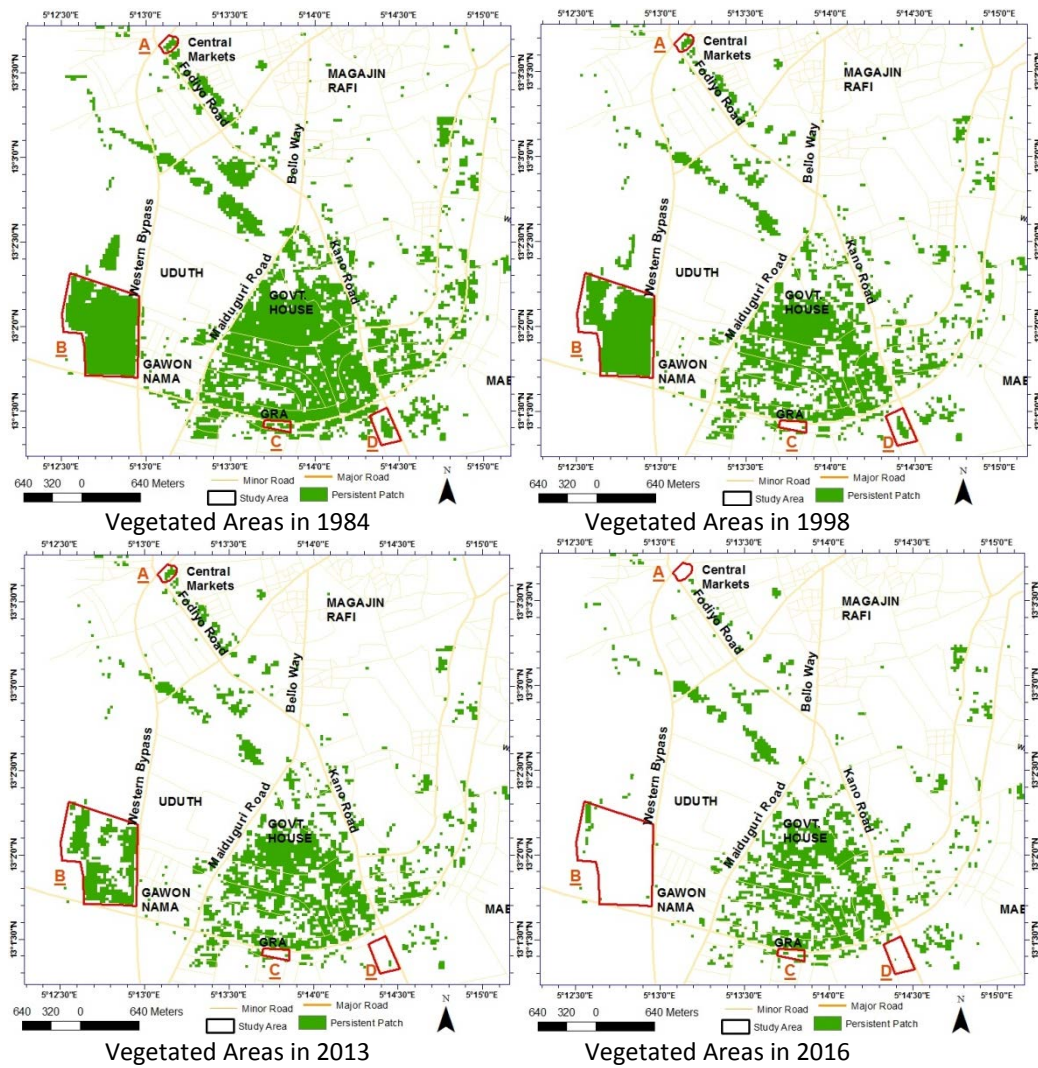


Figure 2: Map of the Study Area showing lost and Persistent Vegetation Patches

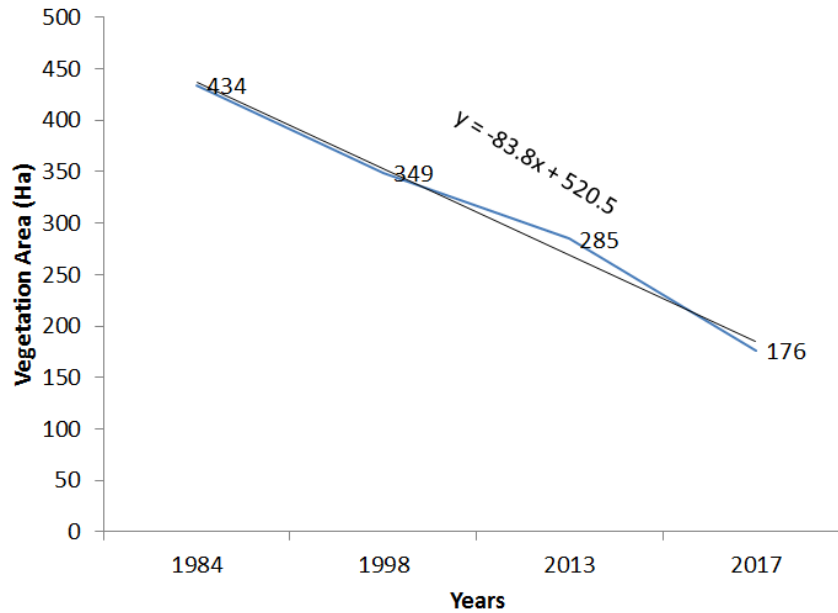


Figure 3: Vegetation Coverage in Sokoto Metropolis

Figure 3 indicates a downwards trend in the vegetation cover of the metropolis. The trend equation shows that a total depletion is possible in less than a decade from 2017. Figure 4 also presents downward trends in all the patches. Patches A and D recorded 100% losses between 1984 and 2017, while B and C recorded 96% and 79% losses respectively.

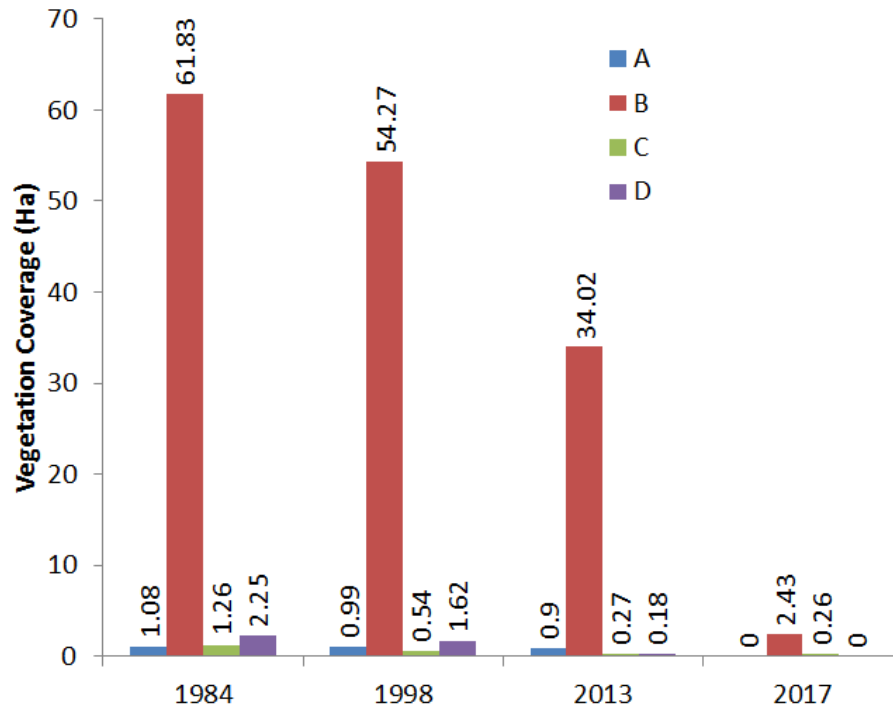


Figure 4: Vegetation coverage in the selected patches

4.2 Biodiversity Field Inventory

The vegetation in the patches consists of scattered trees, shrubs, grasses and forbs. The soil is covered by herbaceous plant and young and regrowth of woody plants. Some herbaceous plants here have become dry and turned into litter or burnt as sampling was done in the dry season of the most recent year.

4.2.1 Woody Vegetation

In the quadrat sampling among the four patches, 34 woody species were counted (both trees and shrubs), belonging to 21 families, the most abundant being those belonging to *Combretaceae* family with species (Table 1). While Patches A and D and their associated biodiversity locally have become totally extirpated and destroyed, Patches B and C are also nearing extinction.

Table 1: Woody Species of the Study Areas

Family name	Local Name (Hausa)	Botanical Name	T or S	I or E	Sampled Plots			
					A	B	C	D
Anacardiaceae	Mangoro	<i>Mangofera indica</i>	T	E	√	√		
	Danya	<i>Sclerocarya birrea</i>	T	I		√		
Annonaceae	Gwandar daji	<i>Anona senegalensis</i>	S	I	√	√		
Asclepiadaceae	Tunfafiya	<i>Calotropis procera</i>	S	I		√		
Balanitaceae	Aduwa	<i>Balanites aegyptiaca</i>	T	I		√	√	√
Bambacaceae	Kuka	<i>Adonsonia digitata</i>	T	I				
Burseraceae	Dashi	<i>Commiphora Africana</i>	T	I		√		
	Hano	<i>Stagannotaenia araliacea</i>	T	I				√
Caesalpiniaceae	Malga	<i>Cassia sieberana</i>	T	I				√
	Kandari	<i>Terminalia microptera</i>	T	I				√
Combretaceae	Tsiriri	<i>Combretum nigricans</i>	T	I				√
	Sabara	<i>Guera senegalensis</i>	T	I		√		√
	Marke	<i>Anogeissus leicarpus</i>	T	I				√
	Kalgo	<i>Combretum glutinesum</i>	S	I		√		√
Combretaceae	Geza	<i>Combretum micranthum</i>	S	I				√
Compositae	Shuwaka	<i>Vernonia colorata</i>	S	I		√		
Ebenaceae	Kanya/Kaiwa	<i>Diospyros mespiliformis</i>	T	I		√		√
Euphorbiaceae	Bini-da-zugu	<i>Jatropha circus</i>	S			√		
Leguminoceae	Dundu	<i>Dichrostachys cimereao</i>	S	I		√		
	Tawatsa	<i>Entanda abyssinica</i>	T	I				√
Meliaceae	Dogon-yaro	<i>Azadarachta indica</i>	T	E	√*	√*	√*	√*
Mimosaceae	Bagaruwa	<i>Acacia nilotica/Arabica</i>	S	I	√	√	√	√
	Farar kaya	<i>Acacia sieberana</i>	T	I				√
	Aduwa	<i>Bolanites aegyptiaca</i>	T	I	√	√		
Mimosoideae	Gawo	<i>Acacia albida</i>	T	I		√		
Minosaceae	Dundushe	<i>Acacia seyal</i>	S	I		√	√	√
Moraceae	Baure	<i>Ficus gnaphalocarpa</i>	S	I		√		√
Moringaceae	Zogale	<i>Moringa oleifera</i>	S	E		√		
Myrtaceae	Gwaiba	<i>Psidun gwajava</i>	S	E	√	√		
	Turare	<i>Eucalyptus camaldulensis</i>	T	E	√			
Palmeae	Goriba	<i>Hyphaene thabaica</i>	T	I		√		

Sapotaceae	Kadanya	<i>Butyraspermum paradoxum</i>	T	I				√
Verbenaceae	Dunya	<i>Vivex doniana</i>	T	I		√		

T= Tree, S= Shrub, I= Indigenous, E= Exotic, * = Dominant Specie

Source: Authors' fieldwork 2007 (for A) and 2014 (for B, C, & D)

4.2.2 Herbaceous Vegetation

In the quadrat sampling for herbaceous plants, 29 species were counted belonging to 20 families. The most abundant is the grass family, Gramineae with 7 species (Table 2).

Table 2: Herbaceous Species of the Study Areas

Family Name	Local Name (Hausa)	Botanical Name	F or G	Sampled Plots			
				A	B	C	D
Amaranthaceae	Alkamar-kwaddo	<i>Pupalia lappacea</i>					√
Amaranthaceae	Zaren-gade	<i>Amaranthus viridis</i>	F	√			
Aristolochiaceae	Madacin-,kasa	<i>Aristolochia albida</i>	F			√	√
Aroideae	Kainuwa	<i>Pistia stratiotes</i>	F		√		
	Bubburwa	<i>Forgrostis tremula</i>	F				
Bramineae	Harkiya	<i>Digitata debilis</i>	G		√*	√	√
Butteriaceae	Hankufa	<i>Waltheria indica</i>	F				√
Caesalpiniaceae	Rai-dore/sanga-sanga	<i>Cassia occidentalis</i>	F	√*	√*	√*	√*
	Tafasa	<i>Cassia tora</i>	F		√	√	√
Caesalpiniaceae	Lalo	<i>Corchorus tridens</i>	F		√		
Commelinaceae	Balasaya	<i>Commelyna nudiflora</i>	F		√		√
Compositae	Kashin-yawo	<i>Acanthospermum hispidum</i>	F		√	√	√
Convolvulaceae	Yaryadi	<i>Ipomoea muricata</i>	F			√	
	Duman-kada	<i>Ipomea repens</i>	F		√		
Gramineae	Kyasuwa	<i>Pennisum lordecides</i>	G	√	√	√	√
	Tsarkiyar-zomo	<i>Cynedon dactylon</i>	G	√			√
	Shinaka/wutsiyar-bera	<i>Ctemium elegans</i>	G		√	√	√
	Danba	<i>Andropogon tectonum</i>	G				√
	Soso	<i>Luffa cylindrical</i>	G			√	√
	Gamba	<i>Andropogon gayanus</i>	G		√		
	Karangiya	<i>Cenchrus cathaticus</i>	G		√		
Lamiaceae	Doddoya	<i>Occimum basilicum</i>	F		√		√
Malvaceae	Garmani	<i>Sida cordifolia</i>	F	√	√	√	√
	Gwiwar-rakumi	<i>Gossypium anomalum</i>	F		√	√	
Rubiaceae	Gaude	<i>Gardenia erubescens</i>	F		√		
Scrophulariaceae	Kuduji	<i>Striga senegalensis</i>	G				√
Solanaceae	Dandana	<i>Schwenckia Americana</i>					√
Urticaceae	Farin-Baure	<i>Ficus vallis-choudae</i>	F		√		
Zygophyllaceae	Tsaïdo	<i>Tribulus terrestris</i>	F		√		√

F=Forb, G=Grass, * = Dominant species

Source: Authors' fieldwork 2007 and 2014.

4.2.3 Wildlife Study

The wildlife and hepatofauna study relied on both observation and qualitative inquiry involving interview with the people acquainted with the local fauna. The sampled patches were/are rich in wildlife presence. Sample B which has a stream traversing it is also rich in hepatofauna. The most abundant wildlife in the study area is invertebrates, followed by vertebrate avian, rodent and reptilian species. Table 3 gives the variety of both invertebrate and vertebrate fauna, found in the sampled areas both on land and in the stream that traverses sample B.

Table 3: Wildlife Composition of the Sampled Patches

PHYLUM	FAMIL Y:- SPECIES
1. Anthropoda	Arachnida: <i>Pandinus imperator</i> , <i>Torania variato</i> , <i>Scodra griseips</i> (jumping spiders), <i>Loxosceles spp</i> (Brown spider), <i>Dermacentor variabifis</i> (work tick), <i>Buthus hottentous</i>
	Diplopoda (millipedes): <i>Oxydesmus spp.</i> , <i>Pachybolus ligulatus</i> , <i>Prepodesmus sp.</i> , <i>Hebrodesmus spp.</i>
2. Annelida	Insecta: Diptera: <i>Culex and Anopheles spp.</i> (gnats), <i>Chironomus sp.</i> (midge) <i>Musa domestica</i> (house fly), <i>Tipula sp.</i> , <i>Psychoda sp.</i> , <i>Chrysops sp.</i> , <i>Tabanus sp.</i> Trachoptera: <i>Agryea sp.</i> , <i>Leptoceffa sp.</i> , <i>Rhodane/laminos</i> Coleopteran: <i>Meflodon downer</i> (longhorn beetles), <i>Anthia spp.</i> (ground beetles), <i>Adalia bipunctata</i> (lady bird) Orthoptera: <i>Schistocera and Locustera spp.</i> (locusts), <i>Sphedromentis lineola</i> (praying mantis), <i>Gryllotalpa Africana</i> (cricket), <i>Zonocerus variegates</i> , <i>Concephalus sp.</i> (longhorn grasshopper). Isoptera (termites): <i>Reticulitames sp.</i> , <i>Amitermis sp.</i> , <i>Cubitermis sp.</i> , <i>MAcrotermis sp.</i> Lepidoptera (Butterflies): <i>Papilio sp.</i> , <i>Limentis sp.</i> , <i>Danaus sp.</i> , <i>Heliohis sp.</i> , <i>Sphinx sp.</i> , <i>Acrea sp.</i> , <i>Precis sp.</i> , <i>Neptis sp.</i> Hymenoptera: <i>Apis sp.</i> (honey bees), <i>Apateles sp.</i> , <i>Qecophylla sp.</i> (white/tailor ant), <i>Monomorium destructor</i> (black ant), <i>Pofistes sp.</i> and <i>Vespa sp.</i> (wasps)
	3. Mollusca
	Gastropoda: <i>Archatina ap.</i> (Giant African land snail), <i>Limocolaria sp.</i> (garden snail)
	4. Chordata
	Amphibian: <i>Bufo Calamita</i> (Natterjack Toad)
	Reptilia: <i>Iguana Iguana</i> (Agama Lizard), <i>Varanus Spp</i> (Monitor Lizard), <i>Riopa Fernandii</i> (West African Skink), <i>Bitis Caudalis</i> (African Viper), <i>Hyperlius Spp.</i> (African Tree Frog), <i>Chameleon Dilepis</i> (Chameleon)
	Mammalian
	Rodenta: <i>Cricetomys Gambianus</i> (Giant Pouch Rat), <i>Funiscious Anerytrus</i> (Squirrel), <i>Afelerix Albiventris</i> (African Hedgehog), <i>Myomis Daltoni</i> (Bush v Mouse), <i>Mus Ninutoides</i> (pygmy Mouse), <i>Rattus Rattus</i> (Black Rat).
	Insectivore: <i>Erinaceau Albiventris</i> (Fair-Toed Hedgehog), <i>Potamogele Velax</i> (Giant Otter Shrew).
	Chiroptera: <i>Eidelon Helvun</i> (Straw Coloured Fruit Bat), <i>Epomops Frongueti</i> (Franquets Fruit Bat), <i>Nycteris Hispdia</i> (Hairy Slit Faced Bat), <i>Taphozous Mautimus</i> (Mountain tomb bat), <i>Rhinopoma Microphullus</i> (Larger Mouse Tailed Bat), <i>Tadarida Nigeriae</i> (Nigerian Free-Tailed Bat)
	Aves: Namida Meleagris ,(Guinea Fowl), <i>Francolinus Clappertonis</i> (Clapperton's Francolin), <i>Polyboroides radiatus</i> (Harrier Haw), <i>Streptopella Semitorqueta</i> (half-coloured red-eyed dove), <i>Columba Guinea</i> (wild-speckled pigeon), <i>Streptopelia Turtur</i> (turtle dove),

	<i>Streptopelia Decipens</i> (mourning dove), <i>Picatus Arithacus</i> (grey parrot), <i>Milvas Migrants</i> (Kite), <i>Otus scops</i> (African scops owl), <i>Stimentopelia Senegalensis</i> (Laughing dove), <i>Tyto Alba</i> (Bam Owl), <i>Neophason monachus</i> (Hooded vulture), <i>Cosmerodius albus</i> (Great white egret), <i>Hiegraetus Spilogaster</i> (African hawk eagle), <i>Apus apus</i> (Common swift), <i>Ceyx pictus</i> (pygmy king fisher), <i>Ardeola ibis</i> (Cattle egret).
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Source: Authors' fieldwork 2014.

Some aquatic and amphibian species were observed swimming in the said stream and/or resting on its banks, crawling across trails or on plants, basking in the sun, feeding or hopping away. Invertebrate species include those belonging to the following phyla: Annelida, Anthropoda, Diplopoda, Mollusca and Insecta. Vertebrate species consist of those belonging to the phyla of Chordota, and they include the following family classes: Amphibia, Reptilia, Aves and Mammalia.

5. Discussion

The trend of negative changes in vegetation for all the sampled sites shows the rapidity of urbanisation of Sokoto metropolis. Eniolorunda (2010a) earlier observed 16% loss of the Giginya Greenbelt (Site B) between 1986 and 2005, adding that the area was not under any serious management. Yelwa *et al.* (2009) also observed that between 2003 and 2009, Sokoto metropolis expanded by 15.82%. The authors concluded that such an expansion had effect on any form of fallowed land. Eniolorunda (2010b) declared that Sokoto metropolis expanded in size by 201% between 1985 and 2007, while Eniolorunda *et al.* (2012) argued that residential land use would expand by 31% and non-residential land uses within the built-up area by 27% between 2005 and 2020. As urban expansion progresses in the study area, degradation of more vegetation patches is anticipated. This is already evident in the depletion and near-depletion of the study patches.

Plant species perform utilitarian functions by providing certain direct or indirect economic/utilitarian products/services to

human societies. The result of the interview with the local people has shown that plant products are used as food (fruits, food supplements, vegetables), feed for livestock, medication, biomass fuel, domestic implements (such pestle and mortar, hoe handle, etc.), hedges on farms (to demarcate boundaries), building materials, gums, fibres etc. These uses have been corroborated in the literature elsewhere on the globe (Siddle, *et.al.* 1985; Alonso *et al.*, 2001; GFA, 2001). Documentary sources have also stated ecological services performed by plants such as those vegetation patches to include: retardation of soil loss, protection against wind and water erosion; they are also said to contribute to soil management through humus accumulation, nitrogen fixation, and nutrient pumping from deeper layers. In addition, the vegetation stabilises local, regional and global climates, provides for pollution control and act as carbon sinks. Plants are also aesthetically pleasing and their green foliage improves eye sight (Schneider, 1979; Alonso, *et.al.* 2001; GFA, 2001; Adamu, 2007).

All the faunal species in the study area are said to provide numerous services in such areas as food, aesthetic, industrial, medicinal, ecosystem, eco-tourism and nutrient cycling provisions. Important faunal products include honey and bee wax provided by the honey bee, which are significant food, medicinal and industrial products, edible protein products, non-edible products such as bones used as calcium sources and trophies, skins; invertebrates, rodents and apes used as specimens in scientific and medicinal researches and to test efficacy and side effect

of new drugs and vaccines (Zida and Kologo, 1991; GFA, 2001). It is note-worthy that ecological visits to game reserves, parks and zoological gardens on vacations are said to outstrip attendance to professional sporting events in USA and Canada and constitute an important source of foreign exchange earnings in Kenya and Tanzania (Alonso et al., 2001). Faunal components of the earth system also provide life-sustaining ecosystem services such as soil aeration, pollination and the spread of seeds as well as nutrient cycling (Alonso et al., 2001). They also provide herbivory/insectivory services (GBA, 1995; Roland, 1993).

6. Conclusion

This study has shown that biodiversity resources have been degraded in the study area. We therefore recommend that Patches A and D which have been completely destroyed should be replicated in the neighbourhood. For patches B to C, it is recommended that government should protect such areas to stop further encroachment and fragmentation. This is necessary to continue to enjoy both utilitarian and environmental services /products which they offer. This calls for strong political will on the part of the authority to be responsive in implementing urban planning rules, so as to mitigate further environmental deterioration in Sokoto Metropolis and maintain environmental quality.

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The Landsat data is available via: glovis.usgs.gov

References

- Abubakar S. D. and Eniolorunda N. B. (2016). Effect of Desertification on Some Selected Soil Properties in a Semi-Arid Part of Northwestern Nigeria. *Journal of Geoscience and Environment Protection*, 4, 111-123. <http://dx.doi.org/10.4236/gep.2016.47012>
- Adamu I.A. 2007. *Biodiversity Assessment in the Kwiambana Game Reserve, Zamfara State, Nigeria*, an unpublished Ph.D, Geography Thesis submitted to the Department of Geography, Usmanu Danfodiyo University, Sokoto.
- Alonso A, Dallmeier F, Granek E & Raven P. 2001, *Biodiversity, Connecting with the Tapestry of Life: Smithsonian Institution/Monitoring and Assessment of Biodiversity programme and Presidents Committee of Advisors on Science and Technology*, Washington, D.C. U.S.A.
- Benna Associates. 1982. *Sokoto Master Plan 1982-2003, Final Report*, Zaria.
- Botkin DB. & Keller EA. 1998. *Environmental Science: Earth as a Living Planet*, 2nd Ed. John Wiley and Sons Ltd.
- CBN Reports. 2013. (www.centralbank.org/documents/cbannualreports and www.centralbank.org/documents/publications - accessed on 21/02/2014).
- Chakraborty D, Thakur S, Jeyaram A, Murthy Y .K. & Dadhwal V. 2012. *Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, Vol. 39-B3, pp. 461-466.
- Dantuni D. 2012. *Appraisal of the Implementation of Sokoto Master Plan – 1938-2003*. An unpublished M.Sc. Dissertation in the Department of Geography, Usmanu Danfodiyo University, Sokoto Nigeria.
- Eastman J.R. 2009. *IDRISI Taiga Guide to GIS and Image Processing*. Clark Labs for Cartographic Technology and Geographic Analysis, Clark University, Worcester, MA 01610 USA.
- Eniolorunda N.B. 2010a. An Analysis of the Degradation of the Ginyia Greenbelt Sokoto Metropolis, Using Landsat Data: *Bayero Journal of Social and Management Studies*, Vol. 13 (No 2) pp 139-150.
- Eniolorunda N.B. 2010b. Updating the Land-use Map of Sokoto Metropolis Using Quickbird Satellite Data. In Ogidiolu, A., Musa, S. D., and Ifatimehin, O. O. (Eds): *Contemporary Issues in Infrastructural Development and Management in Nigeria*. Conference Proceedings of Association of Nigerian Geographers, Kogi State University, Nigeria.
- Eniolorunda N.B, Dankani I.M. and Yusuf N. 2012. A Remote Sensing (RS) and Geographic Information System (GIS) Approach to Estimating Electric Power Consumption: A Case of Sokoto Metropolis, Sokoto State, Nigeria. *International Journal of Management, IT and Engineering*, Vol. 2 (9), pp. 231-242.
- Eniolorunda N. B. and Abubakar S. D. (2016). Response of Soil Organic Carbon to Greenbelt Degradation in the Sokoto Metropolis, Sokoto State, Nigeria. *Journal of Geographic Thought & Environmental Studies*, Vol. 14, No. 2, 80 – 93. <http://www.academix.ng/journals/profile.html?id=3300010155>.
- GBA (*Global Biodiversity Assessment*), Heywood, V.H. and Watson, R.T. (eds). UNEP. Cambridge University Press: 1140 pp.
- GFA (*Global Forestry Resource Assessment*), 2001. *Main Report*. Food and Agriculture Organisation of the United Nations (FAO): 477.
- Ibrahim C. 1998. *The Wealth or Health of Nations*. Cleveland, O.H. The Pilgrim Press.
- Ifabiyi I.P. & Eniolorunda NB. 2012. Watershed Characteristics and Their Implication for Hydrologic Response in the Upper Sokoto Basin, Nigeria. *Journal of Geography and Geology*, Vol. 4, No. 2; 2012.
- Johnston C. 1998. *The Wealth and Health of Nations*. Cleveland, O. H. The Pilgrim Press.
- Keay R. W. J. 1959. *An Outline of Nigerian Vegetation*. Federal Government Printer, Lagos.
- Li B., Yu W. & Wang J. 2011. An analysis of vegetation change trend and their causes in Inner Mongolia, China from 1982 to 2006. *Advances in Meteorology*, doi: 10.1155/2011/367854.
- Lunette R. S. And Elvidge (1998): *Remote Sensing Change Detection: Environmental Monitorin, Methods and Applications*. Ann Arbor Press, 121 South Main Street, Chelsea, Michigan.

- McDonald A. J., Gemmel F. M. And Lewis P. E. (1998): Investigation of the utility of spectral vegetation indices for detecting information on the coniferous forest- An overview. *Remote Sensing of Environment*, vol. 66 (3), pp. 250-272.
- Mayhew S. 2009. *Oxford Dictionary of Geography*, Oxford University Press, U.K.
- ODB (Oxford Dictionary of Biology), 4th Ed. 2009. Oxford Press, Oxford, U.K. 641 pp.
- Odjugo P. A. O. 2010. General overview of climate change impacts in Nigeria. *Journal of Human Ecology*, 29 (1), pp. 47-55.
- Olayinka B. 2003. *Senior Secondary Atlas*, 2nd Edition, Longman Nigeria PLC, 52 Oba Akran Avenue, Ikeja Lagos, pp 18-19.
- Oruwari Y. O. & Owei O. B. 2006. *Urban land and Citizenship Struggles in Nigeria: An Analysis of Access from 1976-2006*. CODESTRA, Dakar-Senegal.
- Roland J. 1993. Large Scale Forest Fragmentation increased the duration of tent caterpillar outbreak. *Oecologia* 93:25-30.
- Schneider S. H. 1997. *Laboratory Earth*. New York, Basic: Books.
- Siddle R. C., Pearce A. J. & L'looghlin C. L. 1985. Hillslope and Landuse. American Geographical Union Water Resources Monograph II. Washington D.C. U.S.A. Sokoto,
- Sokoto, Y. I. 2013. *Greenbelt Conversion and Micro Climate Change in Sokoto Metropolis 2002-2010*. An unpublished M.Sc. Dissertation in the Department of Geography, Usmanu Danfodiyo University, Sokoto, Nigeria.
- Tukur H. A. 2009. Socio-Spatial Impact of the Sokoto Road Dualisation Project (1999-2002). An Unpublished MSc. Geography Thesis submitted to the Department of Geography, Usmanu Danfodiyo University, Sokoto, Nigeria.
- Umar A. T. 2013. Evidence of Climate change. In Iliya M. A. and Fada A. G. (eds.): *The impact of climate change on Sokoto State, Nigeria: Evidence and Challenges*, 1st edition, UNDP/Sokoto State Government.
- Yelwa S. A., Eniolorunda N. B. & Badamasi M. M. 2009. Application of Remote Sensing and GIS to Agricultural Land Encroachment: A case Study of Sokoto-Rima Valley, Sokoto. *Journal of Agriculture and Environment*, Vol. 5 (1&2), pp97-107, Faculty of Agriculture, Usmanu Danfodiyo University, Sokoto.
- Zida O. B. & Kolongo SL. 1991. Main Non-Wood Forest Products in North Africa. *Seminar on Forestry Statistics in Africa*. Thesis, Senegal, FAO.