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BIOPHYSICAL MAPPING AND LAND USE ATTRIBUTES OF KANO ECOSYSTEMS, NORTH-WESTERN NIGERIA

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ABSTRACT
The study examines the terrestrial ecosystems component in Kano, Nigeria. The study employed direct digitization using latest Google Earth Image (version 10.3) and National Space Research Development Agency (NASRDA) land use map of the state. Simple descriptive statistics was also used to evaluate units of ecosystems indentified. The results revealed 16 ecosystems of land units within Kano terrestrial ecosystems. Mapping of the study area also revealed anthropogenic cultivation ecosystem Major category of 18,542km² representing 89% while aquatic ecosystem covered a total 506 km² with altitude elevation of 480above the sea level (a.s.l.). Shelterbelts and wind breaks were 458 - 498 a.s.l. with >100 approximate number of patches. Results were discussed and concluded as Kano ecosystem land use attributes revealed an interdependence of units with major terrestrial and minor aquatic ecosystems with the serious anthropogenic interferences which result in systemic loss of valuable units of ecosystems, ecosystem services and biodiversity components. Therefore, government should embark on mass awareness campaign on proper land use and sustainable environmental policies framework in the state should be enacted.
Keywords: Approach, Assessment, Biodiversity, Biogeography, Ecosystem, Nigeria, Terrestrial

INTRODUCTION

Biodiversity and productivity of ecosystems are central issues in ecological component. Ecosystem is the dynamics of interaction between plant, animal, and microorganism communities and non-living environment which function as one (Yang, 2013).These interactions result in symmetrical and asymmetrical damage to the terrestrial component of the ecosystem. Several scholars in the professional field of biology, geography and some important bodies of ecosystem assessment experts such as Millennium Ecosystem Assessment (MEA) have categorised ecosystem as terrestrial, marine, inland, coastal, rural and urban. Terrestrial ecosystems are land-based ecosystems where biodiversity is pronounced as animals, plants and micro-organisms interact with the physical environmental factors to survive and live on. The land-based ecosystems in the world are categorized as forest, dry land, island, mountain, polar, cultivated and urban (MEA, 2005).

At a larger scale, terrestrial ecosystems occupy 144,150,000 km^2 (28%) of the Earth's surface and constitute a complex array of interacting communities of species of plants, animals, fungi and bacteria that are integrated into a functional unit by specific and dynamic relationship (Pravettoni, 2009), these account for economic and sustainable development thereby improving the general human well-being (UN Convention on Biological diversity, 2018). Terrestrial ecosystems stabilizes climate, purifies atmosphere and the organisms depend on sunlight energy for growth and metabolism while providing ecosystem services such as food, medicine, fuel wood, mineral resources and regulatory services such as soil formation, nutrient cycling and primary production (Consortium for Ecosystem Services and Poverty Alleviation in arid and semi-arid Africa (CEPSA) 2008; Herrera-Estrella, 2014). Human alteration of the environment such as the introduction of alien organisms, construction of dams, and modification of streams and alteration of water chemistry of riverine systems due to agricultural, human settlement or industrial activities are regarded as the most factors causing a decline in global biodiversity (Person *et al.*, 2014). Ecosystems response to natural disturbance and anthropogenic pressures has become a major concern (Piggott *et al.,* 2015). Such understanding is essential for the

assessment of the likely resistance and resilience (Tett *et al.,* 2007; Pinto, 2012) of an ecosystem component and its subsequent potential for recovery after being impacted (Statzner and Bêche, 2010). Local and regional scale impacts must be considered in the context of natural climate fluctuations and more recent anthropogenic driven climate change (Parmesan, 2006; Firth and Hawkins, 2011; Mieszkowska *et al*., 2014; Birchenough *et al.,* 2015). At a world scale, the relevance of reliable surface water has long been recognised, not only in terms of animal and human uses, but also for the high ecological and biogeographic value characterising this type of water bodies (Timms, 2007; Moreno *et al.,* 2010). Li, *et al*. (2015) agreed that use and abuse of farm implements and cultivation practices damage the environment. These call for ecosystem assessment of the environment and various communities to ascertain the level of impact or alteration of ecosystem. Ecosystem assessment in Nigeria in recent years revealed high rate of deforestation with a value of 3500km^2 per year as reported by Ravilious *et al*. (2010). These causes changes in terrestrial landscape of various cities and urban areas (Macaulay, 2014). There is a growing interest in urban ecosystem to include cities which should be considered as ecosystem or component of ecosystems. This study will breathe on scope on the delineation of the identified ecosystems units and the services they provided to humanity. Kano ecosystem assessment can be carried out to examine the complete ecosystems so as to determine the linkages between Ecosystem Services (ES) and Human Well-Being (HWB) that is crucial to sustain the flow of ES for HWB (MEA, 2005). Kano state has diverse natural habitat, specific development can impact the city as a whole, as the state in recent time is witnessing high construction activities with felling of trees and destruction of some important ecological habitat of plant and animal species. Economic growth and importation of technological gadgets with the consequent higher use levels of environmental impact materials in urban Kano in recent times is occurring at a variable rate (Zakri, *et al.*, 2001).

This study identify and determine ecosystem component areas and other land units in Kano, Nigeria through supervised mapping classification and direct digitization to characterize the ecosystems units. The study will give the useful insight to the conservation ecologists and inform policies for desertification and deforestation control in identified ecosystems areas for biodiversity protection and conservation. The study was informed by the Kano state geographical location and its highest number of population in the country.

MATERIALS AND METHODS

Description of Study Area

Kano State is one of the states in the Federal republic of Nigeria located in the North-Western part. The state lies between longitudes 8° 45 E and 12° 05 E and latitudes 10° 30 N and 13° 02 N and as such is part of the Sudano-Sahelian zone of Nigeria (Fig. 1). The elevation is generally about 650m above sea level but extend up to 1000m above mean sea level at Rishi hills (Olofin, 2014). The climate is the tropical wet and dry type with daily mean high temperature 30^{0}C to lowest 24ºC. The main drainage and hydrology of the state is made up of two major rivers; Kano and Challawa contributing water to the main drainage system Hadejia River system. The soil is mainly ferruginous soils which also contain ferruginous hardpan containing more than 80% proportion of sand (Aliyu, 2008). Vegetation in Kano area is characterised by the Northern Guinea savannah with rich biodiversity at the southern tail and Sudan Savannah with sparse distribution of trees, grasses and shrubs covers the rest of the state.

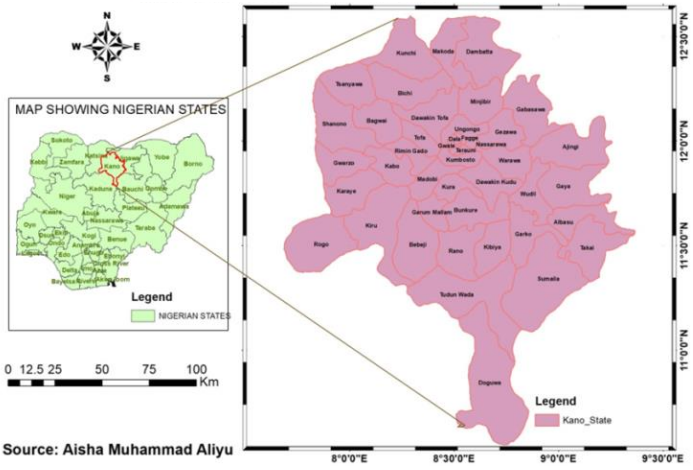

Figure 1. **Map of the Study Area, Kano State**

Supervised Classification and Direct Digitization

The 5 scenes of Landsat 8 images covering Kano state were layer stacked, mosaicked and subset of the image on the basis of Area of Interest (AOI) was done, geometrically corrected, calibrated and dropouts removed following the Butt, *et al*., (2015) and Mukhtar, 2016. During reconnaissance survey, each of the predetermined ecosystems - land units in Kano were identified and the coordinates of 5 training samples were collected for each identified land class using GPS Garming 76csx following Idris *et al.,* 2018. These data were inputted into the Aeronautical Reconnaissance Coverage Geographic Information Systems software (Idris *et. al,* 2018) to guide the classification in choosing the pixels to be selected for each land units. The algorithm adopted for classification of ecosystems, land use and land cover is Gaussian Maximum Likelihood Classifier (MLC) according to Strahler, (1980) and Schowengerdt, (2007). Five major ecosystem categories in Kano were identified. The National Space Research Development Agency (NASRDA) land use map of Kano in 2019 was overlaid on the map produced above in ArcGIS to identify other ecosystem-land units and demarcate boundaries. Smaller land units within the terrestrial ecosystem that are less than 60m^2 were extracted using Google Earth pro 10.3 polygon (Idris *et. al,* 2018). The coordinates were exported to ArcGIS Version 10.3 and converted to layer using the convert Keyhole Mark up Language (KML) to raster tool. The maps were merged to display different ecosystems and land units within the terrestrial ecosystem in Kano. The classification was certified using Ground Truthing Survey Method (GTSM) following (Zhou and Pilesjo, 1996).

RESULTS AND DISCUSSION

Table 1: presents the broad categories of ecosystems found in Kano state; terrestrial (for land units) and aquatic (inland waters; rivers, streams and dams). The study revealed four major terrestrial ecosystem categories in Kano state as the seven categories this corroborates the enumerated categories by Millennium Ecosystem Assessment (MEA) (2005). The Kano landscape is dominated by the cultivated category which is about 18741km^2 (90%) of the Kano land surface (fig. 2). The 90% cultivated ecosystem includes many other smaller land units such as floodplains, riparian, irrigated, gully infested areas. The aquatic ecosystems make up about 2% with approximately 506km^2 of the Kano landscape (table 1). Total terrestrial ecosystem was approximately 20254km^2 (97%) of the total Kano landscape.

Table 2 presents the major ecosystem categories in addition to the 11 other ecosystem types found within the major; sand mining pits, ditches, scrublands, grasslands, floodplains, plantations, shelterbelt and windbreaks, rock quarry or mineral mining site and gully infested areas. Cultivated and irrigated ecosystem farmlands covers 83% of the total landscape. This is not unusual as Kano state has the highest rural population density in West Africa.

Forest Ecosystems in Kano State

This study classify forest ecosystem of Kano as a vegetation of natural plant communities of about 1244 km^2 (Table 2) which are dominated by shrubs and trees of various sizes, mostly reach greater than 5m in height at maturity. These findings corroborate Christie *et al*. (2011).

Table 1: Categorization of Kano Ecosystem Percentage Coverage

Ecosystems	Total coverage (km^2)	Ecosystem categories	Total coverage (km^2)	Percentage coverage (%)
Terrestrial	20254	Forest	1244	6
		Urban	453	2
		Hills and mountains	15	0.1
		Cultivated/Irrigated	18542	89
Aquatic	506	Inland water	506	2
Total			**20762**	**99.1**

Table 2: Terrestrial Units of Kano Ecosystem Approximate Percentage Area (km²)

S/No.	Kano Ecosystem Units	Approx. Area coverage (km²)	Percentage Coverage (%)	Altitude (m) above sea level	No. of Habitats within units	Appr. No. of Patches
1	Forest	1,244	5.97	490-750	4	18
2	Scrublands	29	0.14	478	2	9
3	Grasslands	18	0.09	454	1	4
4	Cultivated	16,712	81.75	458	8	4
5	Irrigated	260	1.3	458	8	4
6	Plantations	3.5	0.02	453	1	>9
7	Shelterbelts & Windbreaks	5.5	0.03	458-490	1	>100
8	Gully Infested Areas	958	4.61	476	1	>57
9	Hills & Mountains	15	0.10	557-1023	3	8
10	Urban	453	1.96	455	5	52
11	Rock Quarry sites	3	0.01	458	1	>30
12	Sand Mining Pit	4	0.02	458	1	>42
13	Ditches	8	0.04	456	1	>60
14	Floodplains/Riparian zones	248/320	2.74/1.58	435	1	>23
Total		**20257**	**97%**			

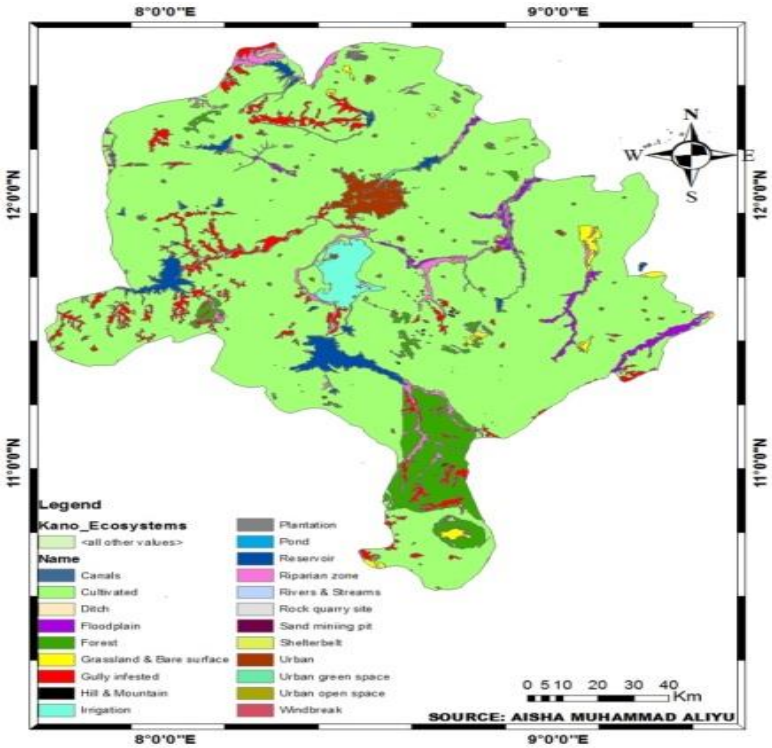

Figure 2: Map of the Study Area Ecosystems Outlay

Other ecosystems land units wetlands, gullies and smaller farmlands were also depicted. Falgore game reserve on the Southern part of Kano was categorized as dry forest and woodland vegetation type of the tropics following Chidumayo and Marunda in 2010. The mapping of the state revealed degradation of forest reserve on the north part of the state mostly in Sakau and Kuskurmi area of the state. This is as a result of lack of conservation and forest management practice. It is imperative that natural ecosystems provide most of the regulatory services that maintain the environment such as carbon sequestration, water quality and air regulation, soil erosion control, biodiversity conservation (Maes *et al.,* 2011). The mapping revealed Scrubland occurs in 9 different places in Kano (fig. 1).

The Scrub Ecosystems of Kano State

The Scrubs land unit are characterized as plants that are less than 5 meters heigh or slightly above 8 meters if multi-stemmed. This type of ecosystem in Kano resulted to area of about 29km^2 (table 2) of the map characterization. These land units strive in areas where there is moisture shortage; high temperatures, evaporation and transpiration as explained by (Zizka and Higgins, 2014). Two types of scrublands were identify in the study: the human altered which suffers devastating deforestation due to anthropogenic activities and natural with indigenous vegetation covered. Similar shrub lands are found in Kiyawa and Birnin kudu in Jigawa and Margi in Adamawa, Nigeria (Geomatics International, 1998).

Grassland Ecosystems in Kano

Grassland ecosystem covers a land area of about 912,351km^2 in Nigeria. This study mapped out grassland of the Kano ecosystem and was found to be more than 18km^2 which represent about 0.09% of the landscape (fig. 3). Seasonal grasslands are ecosystems exhibiting natural dominance of grass vegetation especially during the wet season (Sala *et al.*, 2013). The map characterization study identified 16 different patches of grassland of the terrestrial and the aquatic environment which comprised of Kano Rivers and streams. However, studies by Bengtsson *et al.*, in 2019 stressed that grasslands are major ecosystems of the world existing in every continent, covering a land area of up to one-third or about 40% of the terrestrial surface and concluded that it is also conservation hotspots for grazing of livestock.

Figure 3a: A portion of Ground Truthing Grass Land Ecosystem, Rainy Season

Figure 3b: A portion of Ground Truthing Grass Land Ecosystem, Dry Season

Cultivated Ecosystems in Kano

Several land area of the study site from the map revealed several activities with humans exerted deliberate selective action on the environment these were agricultural ecosystems as classified by Alhamied and Schumacher, (2017).This ecosystem was found to cover a total land area of about 16,972km^{2}and the largest total cover out of the 20,760km^2 total land area of Kano (figure 2), making it the most dominant ecosystem which accounts for 82% of the study area compared to other identified units. Nine other land units found within cultivated ecosystem in study area were; Two main types of cultivated ecosystems were identified in Kano state; rain-fed and irrigation types. Rain-fed agro-ecosystem is mostly practised and characterised by open vast expanse of land made up of sandy loam soil displaying ridges covers approximately 16,688km^2 of the Kano landscape with the cultivated crops mainly millet, maize, rice, cowpea, sorghum and groundnuts locally called Gero, Masara, Shinkafa, Wake, Dawa and Gyada respectively. These were characterised by open vast expanse of land made up of sandy loam soil displaying ridges usually green during wet season. The second Irrigation wetlands, shelterbelt and windbreaks, ditches, ponds, rivers or stream may cut across, plantation, rock quarry site and sand mining pit. Kano State has about 82million hectares of cultivated ecosystem out of 92 million hectares of country total cultivated land. The cultivated ecosystem services provided are foods for humans and animals such as fibres, meat, hide and skin and other valuable human and animal ecological needs. Geometric increase world population has made the Agro-ecosystems dominant with about 30 - 40% of the terrestrial Earth surface.

type was practiced usually close to an open water source like a rivers and streams in the map wells or boreholes were also observed in some farms. Ravines are common in the west and north western part of the state along rivers and streams channels. The farming are characterised by alluvial soil materials which are very loose in structure thus requiring lots of fertilizer and manure. This type of agriculture plays an important role in regional and national economies in many tropical countries (Takeshima and Adesugba, 2015).

Shelterbelts

Shelterbelts are trees or shrubs planted in layers around an open fields within agricultural or range lands and across the large area. They are wind breakers, they improving the structure of the landscape and stabilized and control soil, they also enhance ecosystem services as they were observed as fence for farmlands and orchards in Karfi area of Kura LGA. They were identified to cover about 5.5km^2 (0.03%) of the Kano landscape (fig.1). These land units are used to check desertification in many northern states of Nigeria (Adesina and Gadiga, 2014). Moreover, there are more than 100 patches of the shelterbelts identified in Kano which are scattered all over the north eastern, north western and north central part of the state like Ajumawa in Danbatta local government area. Higher number of shelterbelts in the northern part of the state is due to pronounced desertification encroachment.

Figure 4: Ground Truthing Shelter belt Ecosystem in Kano, Nigeria

Gully Infested Lands

Gully land was also identified as a channel or miniature valley cut by concentrated runoff through which water continuously flows only during and after rains through the gradient channels (fig.). Gullies are rather long, narrow and of uniform width of dendrite channels (Soil Conservation Society of America (SCSA), 1982). Gullies occur on hillsides and undulating plains. However, some gullies in Kano are deep channels with either a U – shape or V-shape often not containing perennial flow, activated only during rainy season. They are commonly found some areas of Kano with approximately area cover 958km^{2}representing about 5% of the land. In Kano, it is locally called *Kwazazzabo*. Gullies are the most destructive form of erosion; their alarming number of occurrence in many states of the country necessitated the establishment of the Nigeria Erosion and Watershed Management Project (NEWMAP) by the Federal Government of Nigeria in 2013 to prevent gullies land formation. Natural remediation were observed in some study area where scrublands develop in some gullies which control flood through excess water draining from farmlands.

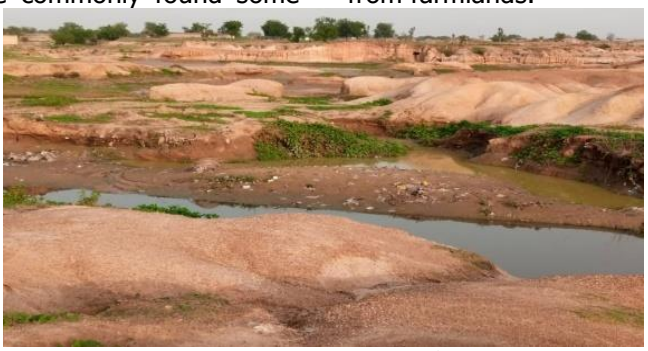

Figure 5: Ground Truthing Gullies Infested Land

Hills and Mountain Ecosystems

Hills and mountain ecosystems were identified of various elevations above the sea level (a.s.l) and slopes which proceed upward at various angles. The land areas covered by this ecosystem in Kano was found to be about 21km^2 (table 2) 0.10% of the landscape (fig. 3). This corroborates with the identifications, classifications and characterizations of hills and mountains of Kapos *et al.* (2000) and Hewitt (2009). However, Rhind in 2000 include areas with isolated massifs rising above their surrounding environment and contiguous ranges. The highest hill elevation in Kano is Rishi hills in Doguwa local government area with height up to 1000m (a.s.l.). However, Chappal waddi hill (2419m a.s.l.) in Taraba state is the tallest hill in Nigeria (Shaw, 2018). Hills and mountains ecosystems account for 32million km^2 about one fifth of the total world terrestrial surface (Kapos, *et al.*, 2000).

Kano Urban Ecosystems

Kano state has the highest population density in Nigeria (Census, 2006) with 44 local government areas out of which 7 are metropolitans area

classified as major urban ecosystem (Annual Abstract of Statistics, Nigeria, 2010).This accounts for higher number of urban settlements due to availability of infrastructural facilities and access to higher quality life facilities in the urban area (Gómez-Baggethun*et al.,* 2014). Kano is one of the states with the highest record of rural - urban migration Oyefara, (2016). Kano ecosystem is classified as Urban Green and Blue Space (UGS) where the built infrastructure covers a large proportion of the land surface (fig 2). Kano map revealed a numerous spaces classified as Urban Open Spaces (UOS), these were football fields, Race course, sport complex and vast number residential compounds. The land area classified as Kano urban ecosystem is approximately 407km^{2}of the Kano landscape (fig. 3). Other similar major urban ecosystems in the country are Lagos and Abuja the former and present capital territory respectively. Human activities remain a major cause of degradation and loss of ecosystems in all parts of the world (Ravilious *et al*., 2010).

Rock Quarry and Mineral Mining Sites

Rock quarry and mineral mining site were identified as places where rocks are quarried to produce building stones and minerals like quartz, tin, zinc and columbine**.** These cover an approximate area of 3km^{2}representing about 0.01% of the landscape (fig. 3). Rocks are mined in different locations in Kano using machines and human effort. The type of rock identified and characterized are granite and gneiss found in Gezawa, Dawakin Kudu, Gwarzo and Kunchi. This is crush by some companies to several tons of gravels of various sizes and boulders of high economic values.

Sand Mining Pits

Sand mining pits identified cover an approximate area 4sqkm (0.02%) of the landscape in Kano (figure 3). They are depressions on the landscape usually found in the villages which constitute factories where mud blocks are mould for local mud house building. The pits owe their origin mostly to government roads construction project as they excavate to satisfy their laterite soil needs. Over 42 pits of diameter sizes were identified in different places covering about 500-1500m^2 area. The land unit provides sand for building as ecosystem services. Another identified sand mining activities is along river beds and floodplains of Kano Rivers and streams principally in villages like Wudil, Malamawa, Karfi and Tamburawa town where two main rivers (River Kano, Challawa, Watari and Joda) confluence.

Floodplains and Riparian Zones

Floodplains identified lowlands area adjacent to rivers that are prone to floods. Alberta in 2008 conceptualised that floodplain are characterised by topography, geomorphology and hydrology and are prone to periodic flooding by the streams. The study revealed that floodplains have an altitude of 435m (a.s.l.) evaluated as 248km^2 coverage area of the landscape. Floodplains are nutrient-rich due to slow flowing water that is supplying the riparian vegetation in this area (Ramey and Richardson, 2017). Riparian zones were identify and classified in the study as transitional zones between aquatic and terrestrial habitat. The areal coverage is about 320km^2 (1.49%) of the Kano landscape spanning from the riverbank. Riparian zones were characterized by gradient which influence the stream ecosystem, ecological processes and biota (Nakamura, 2017). Zones were identified in 23 different locations from supervised classification and direct digitization of the study area. The ecosystem services provided by these zones in Kano are climate regulation, flood control, soil fertility regulation and biodiversity conservation as observed during data collection.

Figure 6 : Ground Truthing Flood Plain of River Wudil, Kano

CONCLUSION

Mapping coupled with ground truthing have been a valuable functional data source for identification and classification of ecosystems types. Kano is rich and diversified in ecosystems dynamics, human activities in the state results in the loss of ecosystems with devastating consequences mostly on the major terrestrial ecosystem due to lack of proper land management practice and conservation. Kano cultivated ecosystem classified indicated higher land encroachment for farming activities with the consequential effect on carbon sequestration, destruction of various habitat of organisms or the prevailing micro-climate. Reserved forests in the study area were under threats with systemic biodiversity loss as the trees are continually fell and animals hunted indiscriminately. A significant number of large freshwater water bodies and there tributaries were observed from Kano map. These constitutes a critical component of Kano ecosystems.

RECOMMENDATIONS

1) Freshwater ecosystem component of Kano should be delineated and investigated.

2) Land conversion and utilization for farming in the state should be done in accordance with established protocols.

3) Forest reserve restoration strategy should be adopted through enactment of the laws in the state.

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