Characterisation of Land Degraded Sites for Restoration Along Kaduna-Abuja Expressway, Chikun L.G.A. of Kaduna State Nigeria

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Abstract

This study characterized sites of degraded land along Kaduna-Abuja expressway in Chikun Local Government Area of Kaduna State for the purpose of planning for the restoration of such sites. Aerial photographs, satellite imagery, topographical sheets and ground data were used. Also examined were types and sizes of degraded sites, distance from major roads and existing land use and cover on an area of 800km^2 (40km/20km) in a GIS environment using on screen digitization classification scheme as well as both descriptive and inferential statistical methods. The results revealed four on-going types of degradations in the area namely; soil erosion at 14 sites, excavation of top soil (42), deforestation (75) and loss of biodiversity (91); while on the basis of size, very small (< 0.5ha; 59 occurrences), small (0.51 – 1ha; 28), medium (1.1 – 1.5ha; 21), large (1.51 – 2ha; 18) and very large (> 2ha; 96) respectively. These are scattered all over the study area and are mostly lands that are not used for any economic and ecological purposes. The correlation revealed an inverse relationship of -0.7 between the distances of degraded sites from the expressway and the frequency of occurrence. The characterization shows that degraded sites are located randomly, but are closer to major roads. The main agents of degradation are the removal of top soil and indiscriminate wood harvest. It is therefore proposed that restoration should start from areas adjacent to major roads, targeting unused land, stopping soil loss and providing a better approach to wood harvest which can be achieved through agroforestry system of agriculture.

Keywords: Agriculture, Degradation, Land, Restoration, Soil.

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Introduction

In the ecosystem services framework, "land" is known as a terrestrial ecosystem that comprises not just soil resources, but also vegetation, water, other biota, climatic factors, landscape setting and ecological processes that operate within one system ensuring its functions and services (MEA, 2005). Land is a major resource for many people in Africa (Adewuyi, 2016). As a result, it contributes significantly to their income. More than half of the population depends on the exploitation of land directly for their long-term livelihood (Allen and Barnes, 1985). They extract/exploit the land in the forms of crop farming, animal husbandry and mining (Banin and Fish, 1995). Many also depend on the land to build their houses while construction companies equally excavate the top soil for various infrastructural development. All of these socio-economic activities are known to impact, often negatively, on the condition of the soil, vegetation and water resources (Adewuyi, *et al*., 2017).

When the impact is negative and continuous over a long period of time, it results in land degradation in different forms. Adewuyi (2011), Lal (2010) and Warren (2002) reported that land degradation can take the forms of loss of biodiversity, decrease in vegetation density, tree cover, revegetation/deforestation, soil erosion (sheet, rill and gully) and reduction in Soil Organic Carbon (SOC). Other causes of land degradation are climate variation/change, bush burning, fuelwood harvesting drought, compaction (physical), salinization, acidification and nutrient imbalance.

Adeel *et al,* (2005) refers to land degradation as "a persistent net loss of capacity to yield provisioning, regulating, and supporting ecosystem services". Millennium Ecosystem Assessment (MEA) considers the ability of land to support primary production as a key ecosystem service (MEA, 2005). Thus, a reduction in net primary productivity (NPP) at a site is often viewed as land degradation (Reynolds *et al*., 2007). Consequently, MEA's definition of land degradation stresses the leading role of primary production among other services as it generates products of biological origin on which other ecosystem services depend. The primary production regulates energy, water and nutrient flows in land ecosystems, sequestrates carbon dioxide, and it is the basis of food production and generally provides habitats for species (MEA, 2005). This conception forms the theoretical framework on which mainstream Remote Sensing-driven assessments of land degradation are grounded (Bai, Dent, Olsson, & Schaepman, 2008; Le *et al*., 2016; Wessels, Prince, Frost, & van Zyl, 2004 and Dubovyk, 2017).

The Sustainable Development Goal (SDG) 15 aims "to protect, restore and promote sustainable use of terrestrial ecosystems, to sustainably manage forests and combat desertification, as well as to halt and reverse land degradation and halt biodiversity loss" (UN, 2015). The recently proposed indicator to assess achievements related to the SDG target 15.3 "proportion of land that is degraded over total land area" has just been confirmed by both the Inter-Agency and Expert Group on SDG indicators (IAEG-SDGs). There is, however, currently no approved recommended methodology by the United Nations Convention to Combat Desertification (UNCCD) to calculate this indicator. Initial, the IAEG-SDGs agreed that the indicator 15.3 would be derived by summing all areas subject to change, which conditions are considered negative due to land degradation, namely land cover and land cover change, land productivity and carbon stocks above and below ground.

Land degradation 'no matter the form and extent' is inimical to the socio-economic development of any area because it reduces the productivity of the land which subsequently reduces the income and standard of living of those who depend on the land. Some of the recent challenges faced by residents of these areas are reduction in crop yield, reduction in size of land available for agriculture (crop farming and animal husbandry), limited land use options, increase in cost of conservation, forceful migration, hostility and of course poverty (Abubakar, 2000).

The trend observed is that the land barely provides sufficient livelihood support to the current users, let alone carrying significant potential for the survival of future generations (Adewuyi and Mustapha, 2017). Hence, there is the need to question the sustainability of the current trend of land utilization in the short, medium and long-term effects and to devise means of restoring the land to cater for both the current and future generations.

However, addressing this question requires baseline data on the types and spatial extent of areas affected. This will help to determine the types of restoration techniques that should be adopted, define the scope of operation, simplify the estimation of cost and establish the necessary re-orientation of the land users to forestall future occurrence. Also, well-informed planning and policy decisions, which are related to the sustainable land management (SLM) and to "zero net land degradation" target, require, credible and spatially explicit information on degraded lands (Stavi & Lal, 2015). The availability of spatial data on land degradation is also a precondition for the implementation of land rehabilitation measures (Winslow et al., 2011; Dubovyk, 2017).

According to Dubovyk (2017) remote sensing allow retrospective analyses of the state and development of land on different spatial scales. Satellite imagery confirms to the principles of repetitiveness, objectivity and consistency, which are preconditions in the framework of Land degradation monitoring. Consequently, Remote Sensing provides important information for integrated approaches combining satellite data with specific tools, geographic information system (GIS) analysis and modeling techniques (Röder et al., 2008). Among different methods for studying and monitoring land degradation, Remote Sensing provides a cost-effective evaluation over extensive areas, where as in situ process studies are resource demanding, and thus, are usually conducted at a field level (e.g. Bai &Dent,2009; Princeetal 2009; Gao & Liu, 2010; Vlek, Le, & Tamene, 2008). In addition, satellite-based assessment is currently the only means for land degradation monitoring at different spatial and temporal scales in a spatially explicit and continuous manner, specifically in the less developed countries where funds for SLM programs are often limited (Sivakumar and Stefanski 2007).

Geospatial mapping and characterization of land degraded sites is undoubtedly one of the first steps for any successful land restoration operation because without sufficient data, proper planning for its restoration will be difficult to achieve. In addition, time is of essence because the more the time for restoration is delayed, the more exacerbated the problem would become and the more expensive it would be to ameliorate.

Many studies have been carried out on land degradation. However, because land degradation study is an inter-disciplinary challenge (Daily and Ehrlich, 1999), the approach varies from mapping (Katawatin and Sougukchan, 2011), assessment (Abubakar, 2000), restoration (Lal, 1999 and 2000), rehabilitation (Oyama, 2011), and management of pollution (Adejumo, Togun, Adediran and Ogundiran, 2010), as well as establishing the relationships of variables (Adewuyi and Olofin, 2017). One common denominator to all these studies is that the scope of coverage in terms of space is very small. As a result, it will take a long time, a lot of physical strength and higher cost to expand the area to be covered. Also, there are no systemic approaches to the amelioration of land degradation over a large area, and as such, the treatment given to each site is site specific.

As a result, the researcher in this study believes that in order to have a comprehensive and cost-effective approach to the restoration of any piece of land degraded; the first step is to identify and characterize the type of land degradation. A database can thus be established for the subsequent land restoration operations. Therefore, as the problem of the study is to ensure sustainability of available land resources, it becomes mandatory to gather information on the nature and pattern of land degraded at sampled sites. Consequently, the study sets out to provide answers to such questions as: where are the degraded sites? What are their sizes? What is the pattern of their distribution? And what type of degradation is ongoing therein? How best can it be stopped in order to restore the status of the land?

The novelty of this study is in the creation of databases on degraded sites on a relatively large area for regional restoration rather than the common point to point approach. In the long run, this will help to prevent, reduce and reclaim lost land. This study is embarked upon on a segment of land devoted to agricultural use along Kaduna – Abuja expressway in Chikun Local Government Area (LGA). This area was selected for reasons of accessibility and abundance of farmlands, as farming is the major occupation of the people. The temporal period of investigation is the dry season, starting from November, 2016 to May, 2017. This is when most degraded sites are very visible for demarcation and measurements needed for the subsequent characterization, using remote sensing and field validation methods. As a result of the approaches adopted for the study, gully erosion, plant desiccation, deforestation and excavated sites are the variables considered for assessment and characterization.

Description of the Study Area

The study area is Chikun L.G.A. in Kaduna State which lies within the Guinea Savanna ecological zone. Specifically, two wards, Kakau and Gwagwada, along the Kaduna-Abuja Expressway axis, were selected due to easy access, availability of various sizes of farmland and the observed dynamic agricultural practices (Figures 1 and 2). The LGA is located within the area bounded by Longitude $7^{o}10^{1}16^{11}$E and $7^{o}35^{1}30^{11}$E and Latitude $11^{o}10^{1}59^{11}$N and $11^{o}25^{1}44^{11}$N. The area has an average elevation of 625m above mean sea level with a surface area of approximately 4690.1km^2. It constitutes a part of the Kaduna Metropolis, which makes the study area to be partly urban, peri-urban and rural in nature, and one subjected to dynamic pressure on its natural resources. It is drained by River Kaduna and its tributaries and characterized by flat and rolling terrain in most places, except for few places along Kajuru axis that is rocky. The population as at 2006 comprised of 372,272 people who occupied 79,451 households, and is currently estimated to be 518,077 people and 110,564 households based on a growth rate of 3.05% as indicated by the National Population Commission (NPC, 2006) for the area. Thus, the current population density would be about 110.46 persons per km^2. This means that the area is diverse in composition, population density, economic activities and pressure. This makes it a suitable area for the targeted land use modeling. However, only 800km^2 (40km/20km) was used for the study.

The area belongs to the Tropical Dry and Wet climate (Aw) with a mean annual temperature of 25.5°C. April is the warmest month with 28.7°C and December is the coolest month with 23°C. During the dry season, when the whole country is under the influence of the Northeast Trade wind starting from November through the month of March, the areas are completely dry. In fact, starting from December through February, the area is under the influence of a severely strong dry wind (harmattan) and with additional influence of the high Plateau of Jos. This is when the harmattan comes around in which we experience a seasonal air current that begins with dust from the Sahara. The mean total annual rainfall for the year is 1200mm while the month with the highest precipitation is August with up to 180 rainy days in a year and an average of 10 hours of sunshine per day (Climate data, 2017).

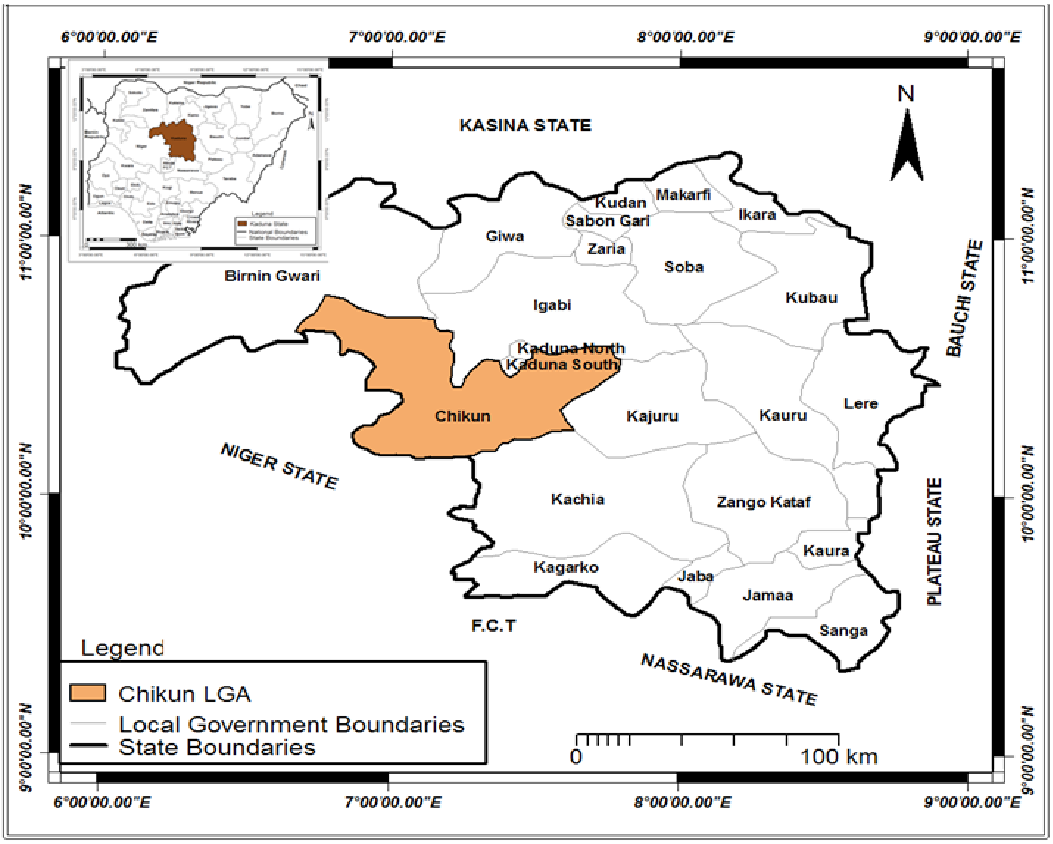

Figure 1: Chikun Local Government Area in Kaduna State.

Source: Kaduna State Ministry of Land and Country Planning, 2015

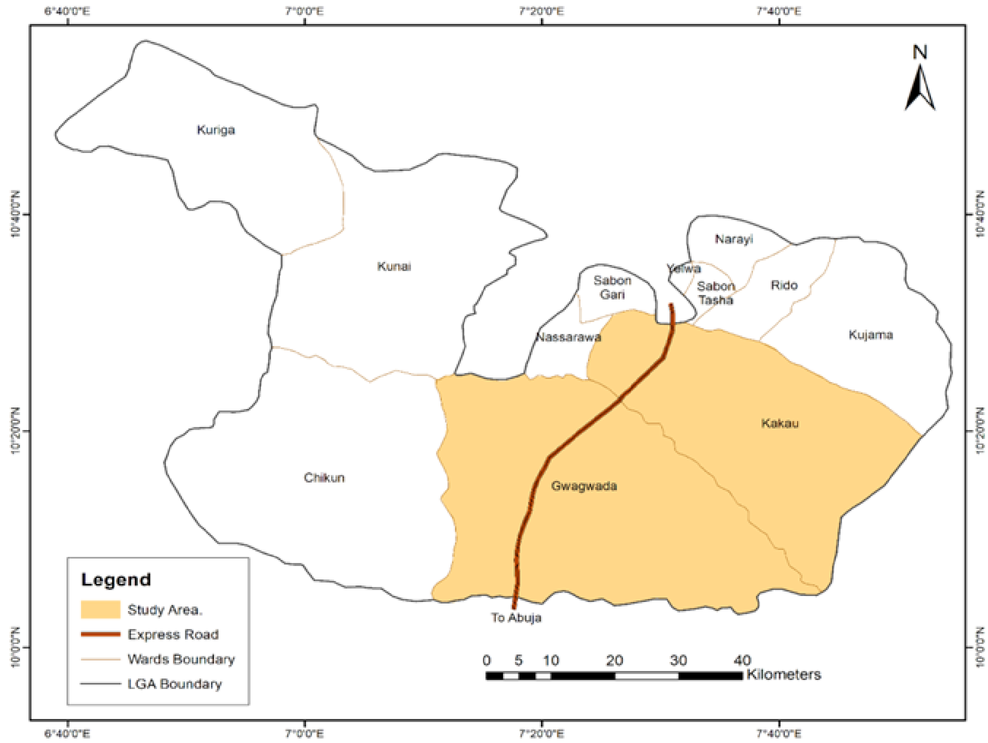

Figure 2: The Study Area within Chikun Local Government Area

Source: Kaduna State Ministry of Land and Country Planning, 2015

The area also belongs to the crystalline Basement Complex part of the northern Nigeria and the soil is mainly of the Tropical ferruginous type, derived from the regolith of the Basement complex. In some places, these soils are covered by a layer of Aeolian drift materials. Soils in the upland are rich in red clay and sand but poor in organic matter. While soils within the flood plains are rich in kaolinitic clay and organic matter and are referred to as Fadama soils. These are generally well drained and mostly sandy-loam and loamy soils on plains while in the valleys, there are hydromorphic soils that are rich in mineral content. Therefore, the soil can support the high agricultural productivity in the area which is the main land use and occupation of the people in the area.

Grasses dominate the vegetation of the area with scattered trees and woody shrubs as well as fringe forests along rivers and streams. Agricultural activities (mainly crop cultivation and animal grazing) have modified the land use and cover and the area is now dominated by crops such as rice (*oryza sativa*), maize (*zea mays*), guinea corn (*sorghum bicolor*), groundnuts (*arachis hypogaea*), millet (*pennisetum americanum*), beans (phaseolus vulgaris), yam (*dioscorea spp*), cassava (manihot esculenta), cocoa yam (*colocasia esculenta*), sugar cane (*saccharum officinarum*), soya beans (*glycine max*), potatoes (*ipomoea batatas*) and fruits trees such as mango (*mangifera indica*), banana (*musa paradisiaca*), oranges (*citrus sinensis*) and guava (*psidium guajava*). The vegetables found in the area are spinach (*spinacia oleracea*), tomatoes (*lycopersicon esculentum*), pepper (*capsicum spp*) and onions (*allium cepa*). Many farmers also rear animals such as cows, sheep, goats, pigs and assorted poultry birds at different scale.

Materials and Method

The main material for this study was the documentary aerial photographs from Kaduna Geographic Information System (KADGIS) of January, 2016 which has a spatial resolution of 28cm. Other supporting materials are the Nigerian topographic sheet Igabi/Chikun SE of 1983, Landsat 8 imagery of 2017, Garmin GPS for field validation and Google map of the area, ArcGIS 10.3 and Erdas 2016 constitute the major software utilized for processing and analysis of the data.

The operational processes followed those of Lillesand *et al*., (2008) which began with interpretation, identification, classification, measurement and categorization of geometrical characteristics of degraded sites for subsequent statistical analysis. Basic descriptive statistical techniques such as percentages, average sizes, as well as inferential statistical techniques such as pair-wise moment correlation were employed. The correlation was carried out to examine the relationships between distance from major road and size of degraded site.

Results and Discussion

The types of land degradation interpreted from the aerial photographs are presented in Table 1 while their locations are displayed in Figures 3 and 4. It is clear that the spatial pattern of the distribution of the degraded sites is scattered over the study area. In terms of frequency of occurrence, loss of biodiversity (complete loss of vegetal cover) has the highest frequency of 91, followed by deforestation (removal of trees) 75, then excavation of top soil 42 and, lastly, 14 soil erosion (sheet, rills and gully erosion) sites.

As for the total area affected by each type of degradation, biodiversity is the most affected in the area with 41.1ha followed by soil erosion (19.4ha), and excavation of top soil 9.4ha, amounting to a total of 69.9ha or 0.1% degraded land out of the 80,000ha expanse of the study area. Since the types of land degradation investigated are related to the existing land use, it is also observed that the land that is under no use has all the investigated types of land degradation. The forest reserve is affected by loss of biodiversity and deforestation while sites of excavation of top soil are associated with burrow pits, though some of the burrow pits are being utilized as fishponds.

Table 1: Types of Land Degradation

S/no.	Types of land degradation	Frequency	%	Area Cover (m^2)	%	Existing LULC
1	Excavation of top soil	42	18.92	938,020.44	13.42	Borrow pit, fish pond and unused land
2	Loss of biodiversity	166	74.77	4,115,411.62	32.68	Unused land and forest reserved
3	Soil erosion	14	6.31	1,937,568.11	27.71	Unused land
	Total	222		6,991,000.18		

Source: Field work, 2017

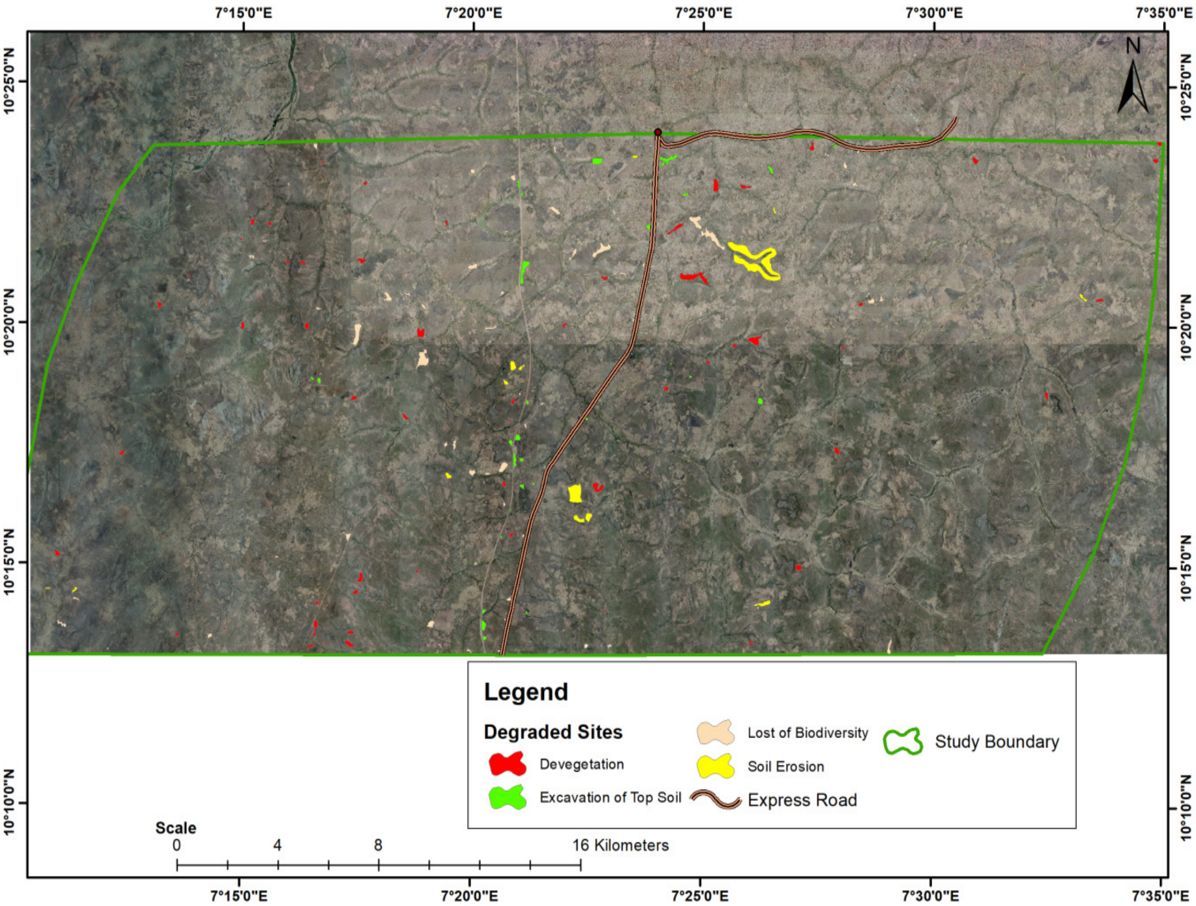

Figure 3: The Land Degraded Sites from the Aerial Photographs.

Source: Field work, 2017

One interesting aspect of the findings is that cultivated areas are not degraded, while areas used for other economic activities are mostly affected. The main cause of degradation is related to activities around vegetation and soil, and the impact did not follow any particular pattern but rather scattered over the study area as observed in a similar study conducted by Mohawesh *et al* (2015).

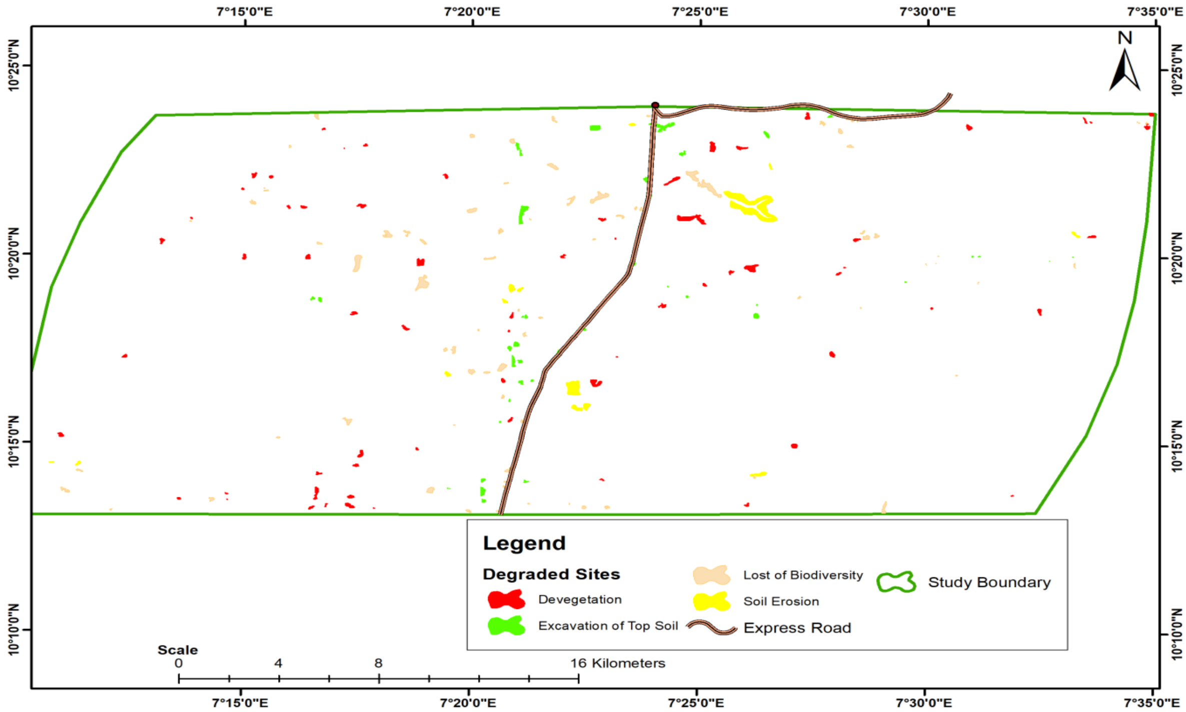

Figure 4: The Spatial Distribution of the Degraded Sites.

Source: Field work, 2017

The degraded sites were further analyzed to categorize them into class sizes as presented in Table 2. The class sizes adopted and their overall frequencies are as follows: very large size (>2ha) with the highest frequency of 43% followed by very small size (< 0.5ha) 27% while the medium size (1 – 1.5ha) has 21%, large size (1.5 – 2ha) 18% and the small size (0.5 – 1ha) has 13%, respectively. This implies that many degraded sites are already large while several others may be at different stages of expansion to become very large in size; a lot are just emerging as degraded sites.

Table 2: Categorization of Degraded Sites

S/no	Category	Size (m^2)	Frequency	%	Existing LULC
1	Very small	< 5000	59	26.58	Fish pond , borrow pit and unused land
2	Small	5001 – 10000	28	12.61	Borrow pit, unused land and forest reserved
3	Medium	10001 – 15000	21	9.46	Unused land and forest reserved
4	Large	15001 – 20000	18	8.11	Unused land and forest reserved
5	Very large	> 20000	96	43.24	Unused land and forest reserved

Source: Field work, 2017

The implication of this is that the factors that trigger land degradation have already existed in the study area for quite some time. As a result, other factors have helped to expand the size of the area affected thereby making some areas already large, with many at different stages of expansion. The most frightening is the quantum number (59) of the newly emerging degraded sites observed in the field. It implies that if nothing is done, in few years' time, there will be several large sizes of degraded sites with serious consequences for the environment as well as enormous economic implications for remedying such degraded sites by individuals and the government. These findings also corroborate the already known fact that when conservation measures are delayed, the problems become larger and remediation may become difficult and very expensive to carry out (Adewuyi, 2010; Wang *et al*., 2015). The implication on the ecosystem is that such patches of degraded sites can eventually change the area into a desert in the desertification process.

A further examination was carried out on the relationship between the locations of the degraded sites relative to any existing major road. A correlation of -0.7 was computed which indicated an inverse relationship between distance of the degraded site from major roads and the frequency of degraded sites. That is, the farther the distance from the major road, the lower the rate of occurrence of land degradation sites. This is so because, both the vegetal resources and the soil that are removed are bulky and not easy to transfer from one location to another for use, so good roads are needed for transportation of such.

A close look at Table 3 also reveals that most of the degraded sites which are less than a kilometre from main roads are burrow pits and unused land while all other categories of degradation are located at distances that cut across all the land uses and cover. In any case, 50% of the degraded sites are located within 5km of a major road. This finding confirms that proximity to a road is a major factor in the rate of occurrence of land degradation and their pattern of distribution.

Table 3: Proximity of Degraded Sites to Major Roads

S/no	Distance from major road (m)	Frequency	%	Existing LULC
1	< 1000	42	18.92	Borrow pit and unused land
2	1001 – 5000	69	31.08	Fish pond, borrow pit, forest reserved and unused land
3	5001 – 10000	54	24.33	Fish pond, borrow pit, forest reserved and unused land
4	10001 – 15000	31	13.96	Borrow pit, forest reserved and unused land
5	>15000	26	11.71	Forest reserved and unused land

Source: Field work, 2017

Implication for Restoration of Degraded Sites

The findings of the study have added credence to the fact that vegetation plays a very important role in ecosystem balancing (Adewuyi *et al*., 2017; Bruijnzeel, 2004; Cole and Brown, 1976). It also further buttresses the importance of soil to the ecosystem balancing and prevention of land degradation (Adewuyi and Baduku, 2012). The removal of vegetation cover (trees, shrubs and grasses) and top soil leaves the earth surface naked and completely exposed to the various agents of land degradation (water, wind and heat) and this has adverse effects on the ecosystem (Archer *et al*., 2001; Wang *et al*., 2015).

Therefore, the first step towards restoration is to stop the removal of vegetation and the top soil in order for them to provide the essential requirements for vegetal regeneration and subsequent sustainability of the ecosystem. Based on the relationship that was established between frequency and pattern of distribution of degraded sites and major road corridors, the plan for restoration should focus first on areas with good accessibility to road since proximity to roads is a major factor, thereafter, the interiors can be addressed (Easdale, 2016).

In order to reduce the rate of land degradation, soil conservation measures should be adopted. The most important aspect of it is to control soil erosion. There is the urgent need to adopt the mechanical measures which are restricted to arable land such as terrace, ridges contour ploughing and also, the biological measures such as mixed farming, strip cropping, cultivation methods early planting, fertilizer application etc. Also, overgrazing should be controlled by only allowing livestock grazing based on the carrying capacity of the land to reduce degradation. In addition, grazing reserves and cattle routes should be clearly demarcated and general grazing practices improved. Equally, the burning of forest areas and bushes ought to be dejected in view of its negative effects on the land. The use of burning should be brought to its minimal level. This will reduce greatly the loss of vegetation that provided cover and protection against degradation.

The protection of the environment is an essential part of development. Through environmental education, people will have a better awareness of their environment and acquire the knowledge, values; skills and experiences that will help them solve their present land degradation problems and prevent future occurrences. Government should mount public information campaigns, promote research in sustainable agricultural technologies and support traditional land management. The government's poverty alleviation efforts should be given emphasis to the rural areas to reduce the level of poverty. Government should introduce various programmes to take people off land vegetal cover and to reduce dependence on firewood as their main source of power. The farming practices in the rural areas should emphasize on long-term sustainability (Ladan, 2004).

Lastly, agricultural land use makes greater use of the land because of its economic importance to the people (Adewuyi, 2011); as a result, all the unused land should be converted to farm lands since it will prevent people from engaging in indiscriminate tree cutting and soil excavation, which tempers with the land fertility and ecosystem stabilization. Also, strong laws should be put in place to prevent those who live on harvesting trees for fuelwood as a lazy profession to stop. Finally, for the forest reserved areas, there is a need for proper monitoring and a better approach to the harvesting of the trees so as to provide a good balance between ecological and socio-economic services they provide as well as a sustainable approach for replacement of deforested portion (Adewuyi and Olofin, 2015).

Conclusion

This study has characterized land degradation sites along Kaduna –Abuja expressway in Chikun Local Government Area in terms of sizes, frequency, areas affected and distance from a major road. Results have confirmed that the loss of biodiversity is the most degrading problem followed by deforestation, top soil excavation and soil erosion. However, in terms of the areas affected, deforestation leading to loss of vegetal cover affected the largest area followed by soil erosion and the excavation of earth material. The results further brought to the fore the influence of road transportation on the location and pattern of distribution of the degraded sites. The overall implication of the results is that the restoration of the degraded sites would best be based on vegetal and soil restoration which can best be achieved through the adoption of agroforestry system of agriculture at the degraded sites.

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