Environ Earth Sci (2017) 76:505
DOI 10.1007/s12665-017-6844-x

ORIGINAL ARTICLE

Quarrying and its effect on vegetation cover for a sustainable development using high-resolution satellite image and GIS

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Received: 7 July 2016 / Accepted: 18 July 2017 / Published online: 25 July 2017

Abstract Huge vegetal losses caused by unsustainable quarrying practices have limited the role played by vegetation cover in mitigating the global impact of climate change. There is a need for a holistic study that will employ remotely sensed data in GIS domain to determine the extent of the effect of quarrying activities on vegetation cover in the study area. The need for extraordinary details with high accuracy and enhanced imagery has necessitated the use of Geo-Eye-1 satellite imagery with 1-m resolution for 2015. The study was carried out in Ebonyi State where 27 quarry sites were studied in six local government areas where mining activities were operated. The study employed geographical information system, Garmin eTrex GPS receiver and global positioning system. Geographical information was processed using ArcGIS to map the patterns and extent of land use. The findings from the study showed that the visual interpretation of the satellite image confirmed that white patches on the imagery were areas affected by intensified quarrying activities. The very dark green colours were interpreted as forest with no observed human activities. The supervised classification of land use also showed that quarrying activities occupied 0.1% of the study area with a total of 402.855 ha of green cover lost in Ebonyi State due to quarrying operations. Quarrying practices have destroyed arable lands, economic trees and forests in the area. This implies that there is a need for policies to be enforced with strict adherence to sustainable quarrying guidelines and consistent monitoring.

Keywords Sustainability · GIS · Environment · Quarrying · Remote sensing and vegetation cover

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Introduction

Quarrying is the process of extracting useful economic resources from the earth's crust. It is an activity where stones are excavated for the purpose of being employed in the construction of roads, dams and buildings (Ojos Negros Research Group 2008). They are mostly sand, gravel, dimension stone, riprap and crushed rock. Every new building typically requires up to 400 tonnes of aggregates (Brown et al. 2008). They are indeed the core building material in all community buildings and infrastructure. Without the existence and use of aggregates in construction, there would be no built environment. A vast portion of the world's forests and vegetation cover is being destroyed and majority of this loss has occurred within the last 100 years (Howarth and Farber 2002; Kuzu et al. 2011). This has led to increased recent studies on land use–land cover changes and nature conservation strategies (Sarma and Kushwaha 2006; Jiya and Musa 2012; Darwish et al. 2010; Anil and Katyar 2000).

This loss is a result of anthropogenic activities like quarrying, agriculture, urban development, among others.

This interrelation between societies and the environment provides the vital necessity for monitoring and assessing the extent of anthropogenic impacts on the vegetation. Measuring the anthropogenic impacts and investigating the human–environment relationship enable the foundations for effective and sustainable management of the environment (FAO 2000; UNEP 1998).

The exploitation of solid minerals, especially through quarrying activities, happens to cause huge losses in vegetation cover due to the fact that its operations are usually carried out on a large-scale, and the quarry sites are abandoned after the resources have become depleted. The incredible scale of this loss has led to significant changes in vegetation/forests around the world in both developed and developing countries like Nigeria. These operations affect biodiversity (Sala et al. 2000), climate change and the environment's ability to provide ecosystem services (Vitousek et al. 1997; Chase et al. 1999).

The use of remotely sensed image provides data at a range of spatial, spectral and temporal scales. These data can be used to estimate the types of land cover and land uses within the study region. Recording the distribution of land cover provides valuable information for improved management of the vegetation. Spatial and temporal components of land cover can be captured using remotely sensed images. This paper uses remotely sensed image to classify the land uses in Ebonyi State and highlights the areas affected by quarrying activities in the area. Notably, vegetation cover consists of the most observable element of the landscape and reflects environmental conditions of a place. Notwithstanding that, unregulated quarrying practices can have adverse effect on the vegetation cover of an area. It alters the original plant community and landscape as its activities have considerable effect on the environment (IUCN 2004). Unfortunately, the destruction of the natural vegetation is not compatible with sustainable development. Although many countries require reclamation plans for extraction sites like quarries, moreover, undoing all the environmental damage to the top soil and underlying bedrock, water supplies, air, noise and land degradation, destroyed habitats and reduction of aesthetic value is a long and problematic task due to the fact that the land degradation is usually on a vast scale.

Statement of problem/aim of the study

The State population is largely rural with an average rurality index. It is estimated that 75% of the population (over 1.2 million people) live in rural areas (EBSEEDS 2004; Fig. 3). It is endowed with huge and concentrated deposits of both solid and mineral resources within these interior rural lands (Oyibe 2000). These solid mineral resources include both metallic and non-metallic resources like Lead–Zinc, copper, limestone, marble stone, granite among others (Akande et al. 1992). The extraction of these rocks is possible and abundant considering the lithological characteristics of the underlying formation of the area. There are two main geological formations traversing the State. These formations include the Ezi Aku (Turonian age) and Asu River formation (Albian age) with outcrops of other rock formations and igneous rocks (Offodile 2001; Orazulike 1994). The abundance of these natural resources in the State has triggered the excavation and exploitation of quarry resources for over 50 years (Chima et al. 2010).

The existing conditions of these quarry sites and its immediate environment portrays lack of sustainable approach in the extraction of these non-renewable resources. Also, the use of opencast method which engages the help of explosives to split large rocks is used during excavation in these sites. It further makes use of machines to totally clear the entire vegetation cover in order to mine the stones underneath. This continuous process can destroy the green cover, deplete water resources and the water table and degrade air quality while increasing the emission of green house gases (Forbes and Dakin 2003).

Moreover, the area is richly endowed with rich forestry and green cover. This is why 85% of the population engage in agricultural production (EBSEEDS 2004). There is no doubt that the destruction and forest fragmentation of the plants and tree habitat is a threat not only to the local ecosystem, but also could possibly deny both the animals and the inhabitants of their livelihood.

The exploitation of solid minerals, especially through quarrying activities, happens to cause huge losses in lands due to the fact that its operations are usually carried out on a large-scale (Singh et al. 2000). Also, the quarry deposits are usually dispersed within remote rural areas, making it difficult for monitoring by government authorities, hence, leading to quarry abandonment after the resources have become depleted (Eggert 2001; Akanwa 2016).

Singh et al. (2000) studied the impact of mining on land use in India. Darwish et al. (2010) also conducted a study on the impact of quarrying on Lebanon natural resources. Blodgelt (2004) carried out a study on impact of stone quarrying in New Mexico. Knowles and Wareing (1999) worked on mineral exploration in the UK, and Oke and Ibanesebhur (2010) investigated the impact of limestone quarrying on the vegetation and landform in Ogun State, Nigeria. Generally, these studies confirmed that quarrying has altered forest covers, agricultural lands, aesthetics, landscape, water bodies, air quality and the environment.

However, these reviewed studies applied different approaches like remote sensing, GIS, field observations and

photography recording, and interviews to generalize that human activities like quarrying, agriculture, urban development among others can cause immense damage to green cover and the environment. Moreover, these reviewed literatures have not been able to authenticate their findings with ground-truth data to ensure that the areas captured by remote sensing and Google Maps were actually areas affected by quarrying alone. The application of remote sensing generally captures areas where green cover has been destroyed from bush burning, farming and construction works. However, this study takes reconnaissance of this fact, as its main thrust is to determine the effect of quarrying activities on vegetation cover in the study area. In order to achieve the aim, the following objectives were pursued.

1. To classify the land uses in the area,
2. To highlight the areas that have been affected,
3. To determine the extent of degraded lands and
4. To identify the locations where intensive quarrying takes place.

These core objectives of the study have become the gaps as this study seeks to fulfil with the application of remote sensing and GIS authenticated with ground-truth data. This will help the government, environmental managers and all those with vested interest in forest and green cover conservation to comprehensively map out a sustainable development plan for mineral resource exploitation in Ebonyi State.

Study area

The study area is Ebonyi State located in the south-eastern region of Nigeria. It is bounded to the north by Benue State, to the west by Enugu State, to the east by Cross River State and to the south by Abia State. The State is situated between longitudes 7°30′ and 8°30′E and latitudes 5°40′ and 6°54′N. It has a land area of 5935 sq. Km and a population of 2,176,947 based on the 2006 census. It has an annual growth rate of 3.5% per annum (National Population Commission 2006; National Bureau of Statistics 2010). The climate is situated within the Warm-Humid Equatorial climatic belt. It falls within the rainforest belt of eastern Nigeria. The area is characterized by high relative humidity of about 75% and surface temperature of about 27° to 30 °C. The rainy season begins between March 1st and March 11th and ends between November 8th and November 18th. The area has an average temperature of 28 °C (Edit et al. 2011). The area lies in the rain forest/savannah vegetation (Figs. 1, 2, 3).

Materials and method

This study involved primary data collection and secondary data collection. The data for the study were collected through direct field observations, oral interviews, photographs and measurements. The image was captured by Geo-Eye-1 commercial colour imaging satellite for 2015. It was sourced from Inforgraph Consultants, Enugu, Nigeria. It was used to detect the locations of the quarry sites. The Garmin eTrex GPS receiver was used to obtain the coordinates of the quarry locations. geographical information system and global positioning system were used for producing a map of the area and fixing the geographic positions of the locations of the quarry sites, respectively. The census data were collected from the National Population Commission office, Ebonyi State. Then, field visits to site were carried out to obtain ground control points for georeference and ground-truth sampling. Appropriate remotely sensed data were processed using digital image processing techniques. The ArcGIS 9.3 software was employed to derive the land use map, and ArcCatalog was further used to map detailed features on the image. The supervised classification approach was employed for mapping detailed land uses. The Surveyors measuring tape was used to calculate the aerial extent of vegetation cover degradation as result of quarrying in the area.

Results and discussion

The high-resolution satellite imagery of Ebonyi State for 2015 is shown in Fig. 4. The visual interpretation method was adopted in the interpretation of the satellite image. This method required that the analyst knows aspects of the study area as well as the spectral response of the image. The analysed information from the satellite image was also substantiated by the field data collected and photographs as precaution and also as a representative of the real terrain conditions.

Some of the elements of visual image interpretation used in the visual analysis were tone and colour. This was possible as the imagery gave the true colour reflection of images on ground due to its high resolution. Tone refers to shades of grey, ranging from black to white.

The land use map of the study area is shown in Fig. 5. The supervised classification technique was adopted to classify the remotely sensed image. The purpose of the digital land cover classification is to link the spectral characteristics of the image to a meaningful information class value, which can be displayed as a map. This will enable resource managers and scientists to evaluate the

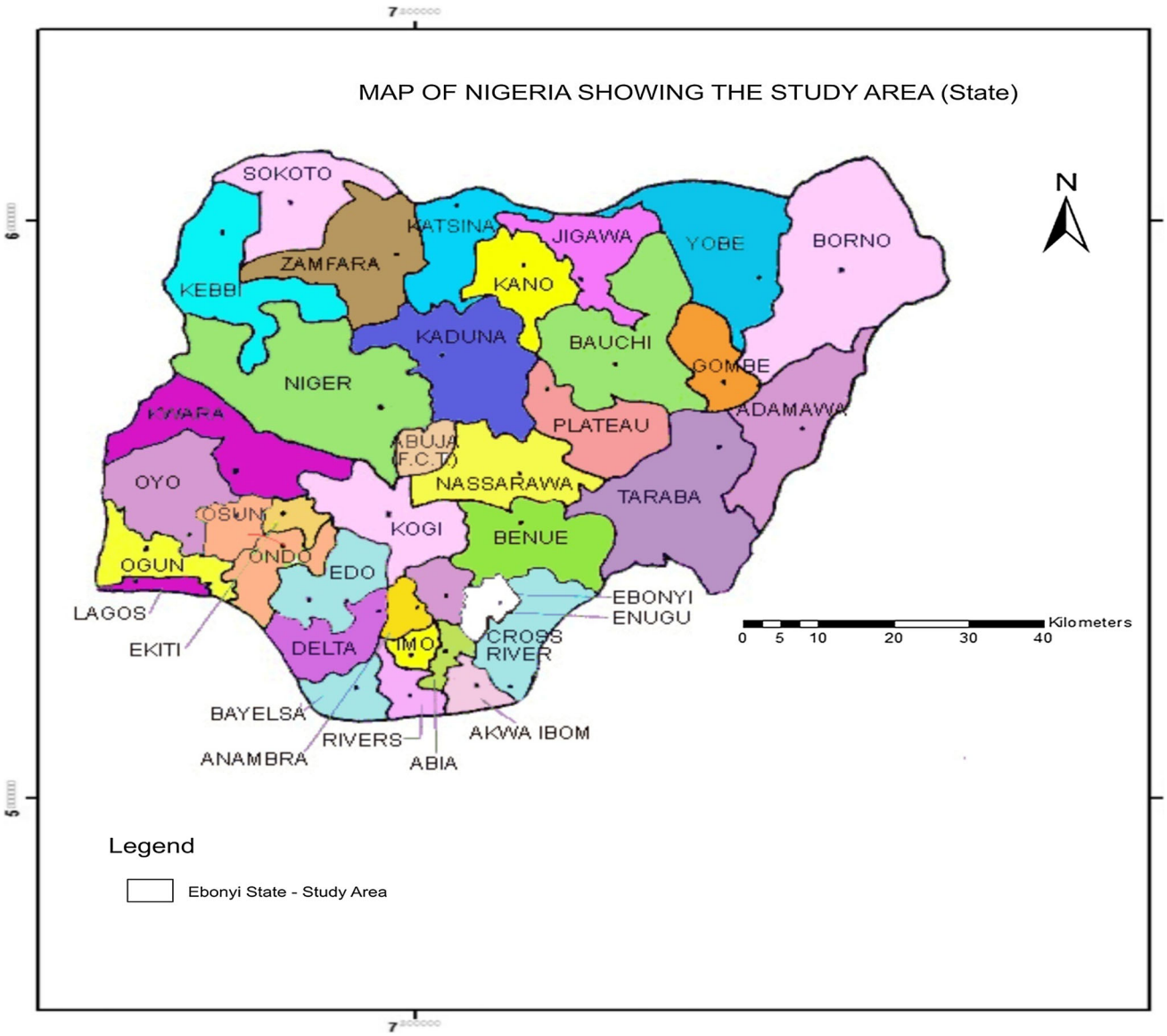

Fig. 1 Map of Nigeria showing the study area

landscape in an accurate and cost-effective manner (Weber and Dunno 2001).

However, this technique identified six classifications of land cover in the area. These are the built-up area (19%), agricultural production (17%), forest (31.9%), stone quarry (13%), bare land surfaces (18%) and water bodies which occupied (1.2%). Table 1 shows the statistical results of classified image.

Furthermore, findings from the land use map of the study area in Fig. 5 reinforce the interpretation made from the satellite imagery and observations during field work. It is evident as interpreted from the imagery that local government areas like Ikwo, Ezza South, Afikpo South, Onicha and Abakaliki LGAs where quarrying activities are not prevalent are rich in vegetation cover indicated with deep green shade. The light green areas indicate cultivated areas and swamp with little human activity. Moreover, it is also interpreted that the local government areas like Ohaukwu, Ivo, Ezza North, Afikpo North, Ishielu and Izzi where quarrying activities are active and concentrated are mainly detected as grassland and savannah areas with intensified human activity.

This shows that human activities, especially quarrying operations, have modified the vegetation cover of the study area. The process of excavation entails the removal of virtually all natural vegetation, top soil and subsoil to reach the aggregate underneath. This is an indication that there are huge alterations of vegetation cover by excavation and exploration of rocks in Ebonyi State. This is in line with the fact that quarrying activities in Ebonyi State date back to the 1950s (Chima et al. 2010) (Fig. 6).

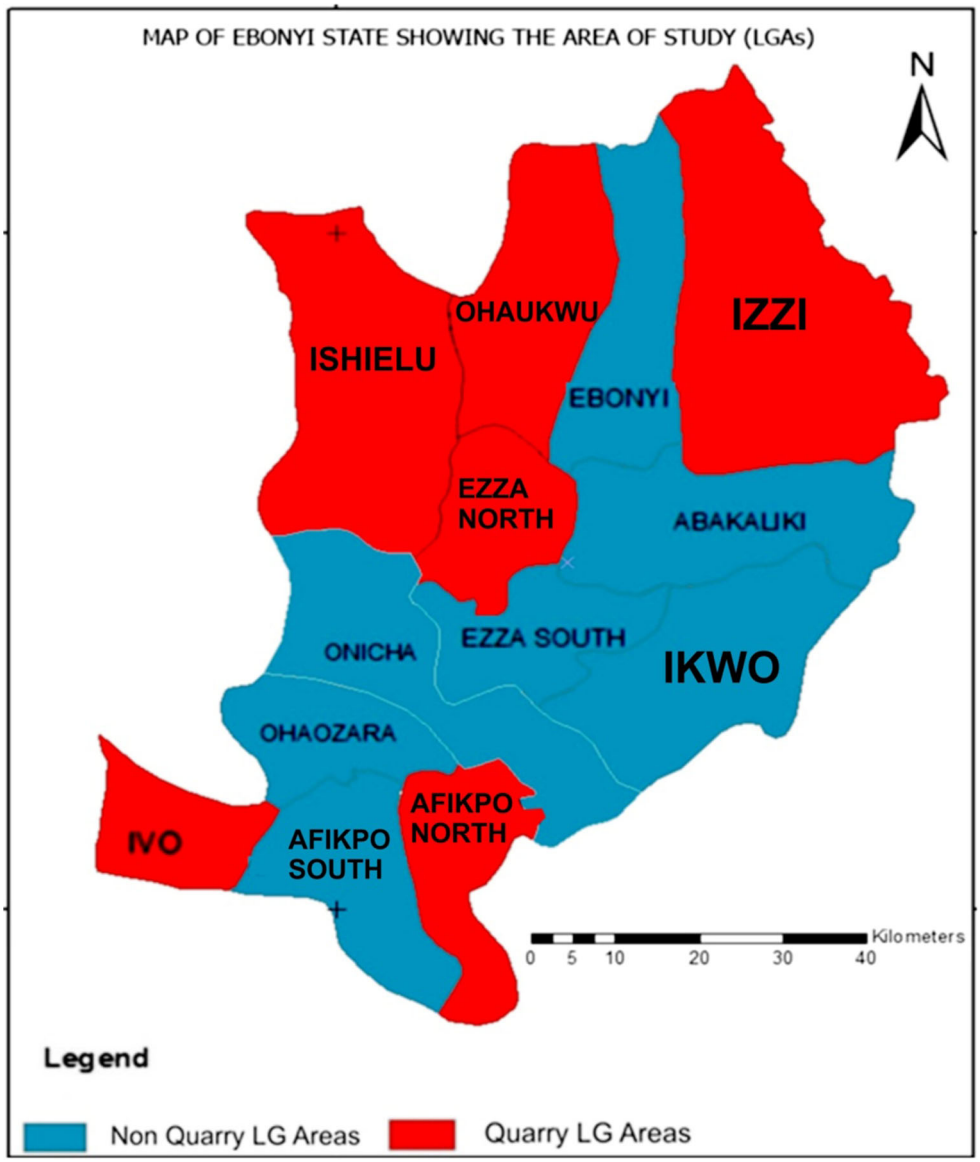

Fig. 2 Map of Ebonyi State showing the Study Area (LGA)

Table 2 shows the local government areas where quarrying activities are active, 27 locations of the quarries, total area lost by quarrying and percentage occupied by mining activities in the area. Also, Fig. 7 shows that a total area of 402.855 ha of prime lands have been destroyed due to excavation of rocks. Ivo LGA happened to have the highest vegetation loss of 142.2 ha represented by 35%. However, Izzi LGA has the lowest vegetation loss of 15.3 ha represented by 4% in the area.

Furthermore, findings from the land use map of the study area in (Fig. 5) reinforced the interpretation made from the satellite imagery and observations during field work. It is evident as interpreted from the imagery that local government areas like Ikwo, Ezza South, Afikpo South, Onicha and Abakaliki LGAs where quarrying activities are not prevalent are rich in vegetation cover indicated with deep green shade. The light green areas indicate cultivated areas and swamp with little human activity. Moreover, it is also interpreted that the local government areas like Ohaukwu, Ivo, Ezza North, Afikpo North, Ishielu and Izzi where quarrying activities are active and concentrated are mainly detected as grassland and savannah areas with intensified human activity (Figs. 8, 9). This is in contrast to the natural rain forest of the area as seen in Fig. 6 due to intensive quarrying operations in the area.

This shows that human activities especially quarrying operations have modified the vegetation cover of the study area. The process of excavation entails the removal of virtually all natural vegetation, top soil and subsoil to reach the aggregate underneath (Fig. 10). This is an indication that there are huge alterations of vegetation cover by

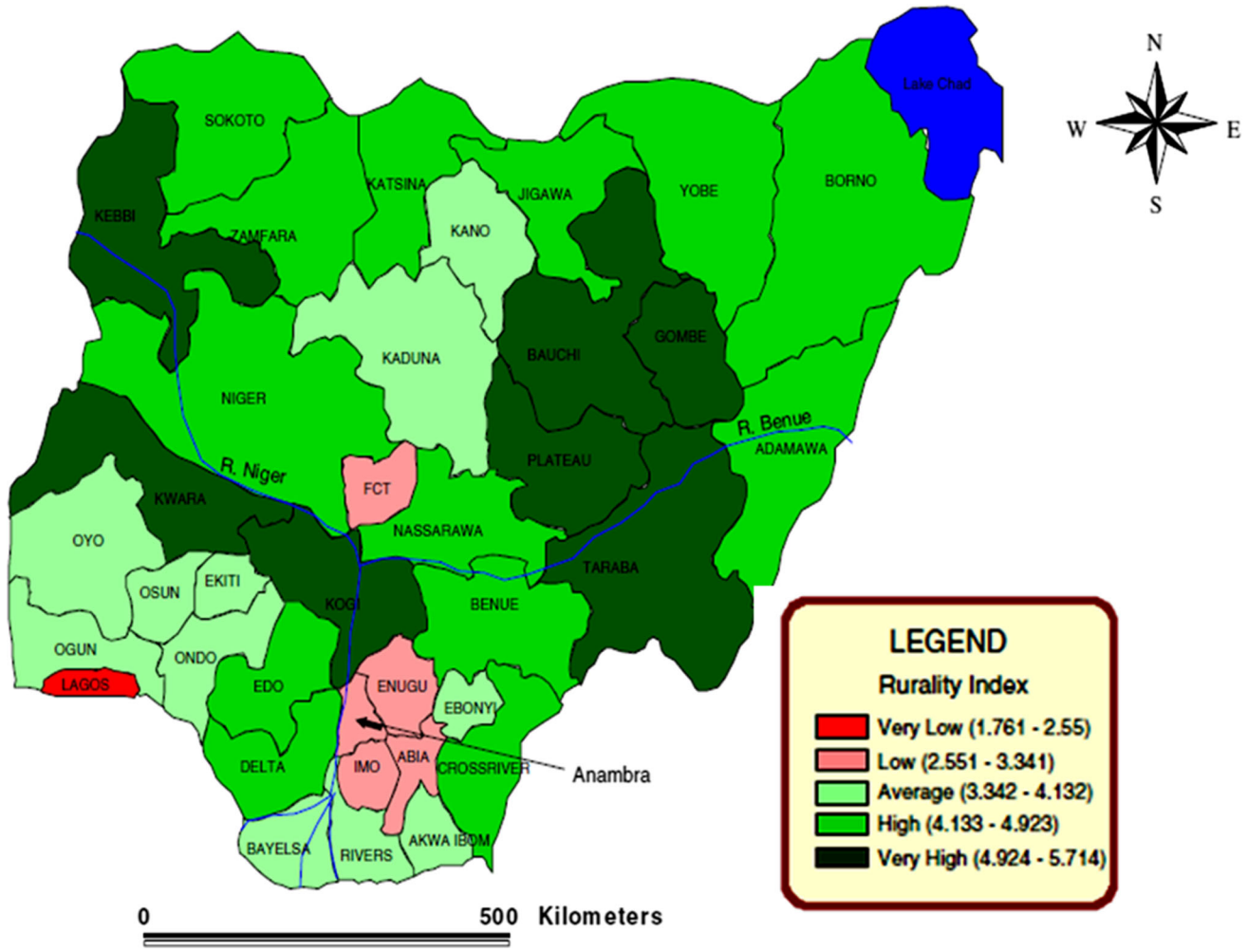

Fig. 3 Map of Nigeria showing the rurality index of Ebonyi State (Google M2016)

excavation and exploration of rocks in Ebonyi State. The results indicate that the uncultivated forest areas occupy the largest activity in the area. The forest/plantations are evergreen forest seen as dark green patches spread across the satellite imagery which occupies mostly the non-quarrying areas. The affected areas are occupied with huge pits, rock piles and debris so that without restoration the land will lie desolate as wastelands. They are interpreted as white–grey patches on the image with red dots showing the pits. The agricultural areas indicated large areas for cultivation and production of food crops. The water bodies, streams and rivers were interpreted as the bluish thread-like lines spread across the image.

The findings from the study as seen in (Table 1) indicated that quarrying activities have affected 0.1% of the land area. Not only has it led to loss of vegetation cover in the area, but it has also affected the existing animal wildlife, loss of biodiversity as plants and aquatic habitats are destroyed and lose their natural habitat. Also, vegetation loss exposes the soil to erosion which further causes loss of growing substrates. This reduces the ability of the surrounding area to support plant life and also hinders plant growth in the area. Unfortunately, vegetation cover is indispensable for food and medicinal uses. It aids in the process of photosynthesis needed for the balance circulation of oxygen and carbon dioxide. Undoubtedly, destruction and fragmentation of plant habitat is a threat to biodiversity and species extinction in the study area.

This paper inferred that based on the findings that the continuous quarrying of rock resources in the area has had a resultant negative effect on the arable lands and vegetation. It is remarkable to note that the study area falls within the rainforest/savannah vegetation (Fig. 6). However, the unregulated quarrying practices have adversely affected the farmlands and forest areas leaving large pits and trenches in the area. Considering that, land and resource management is imperative to sustainable development of Ebonyi State. Sustainable development goals can only be reached when development policies integrate economic and natural resource management planning (Conway 2005). Reviewed

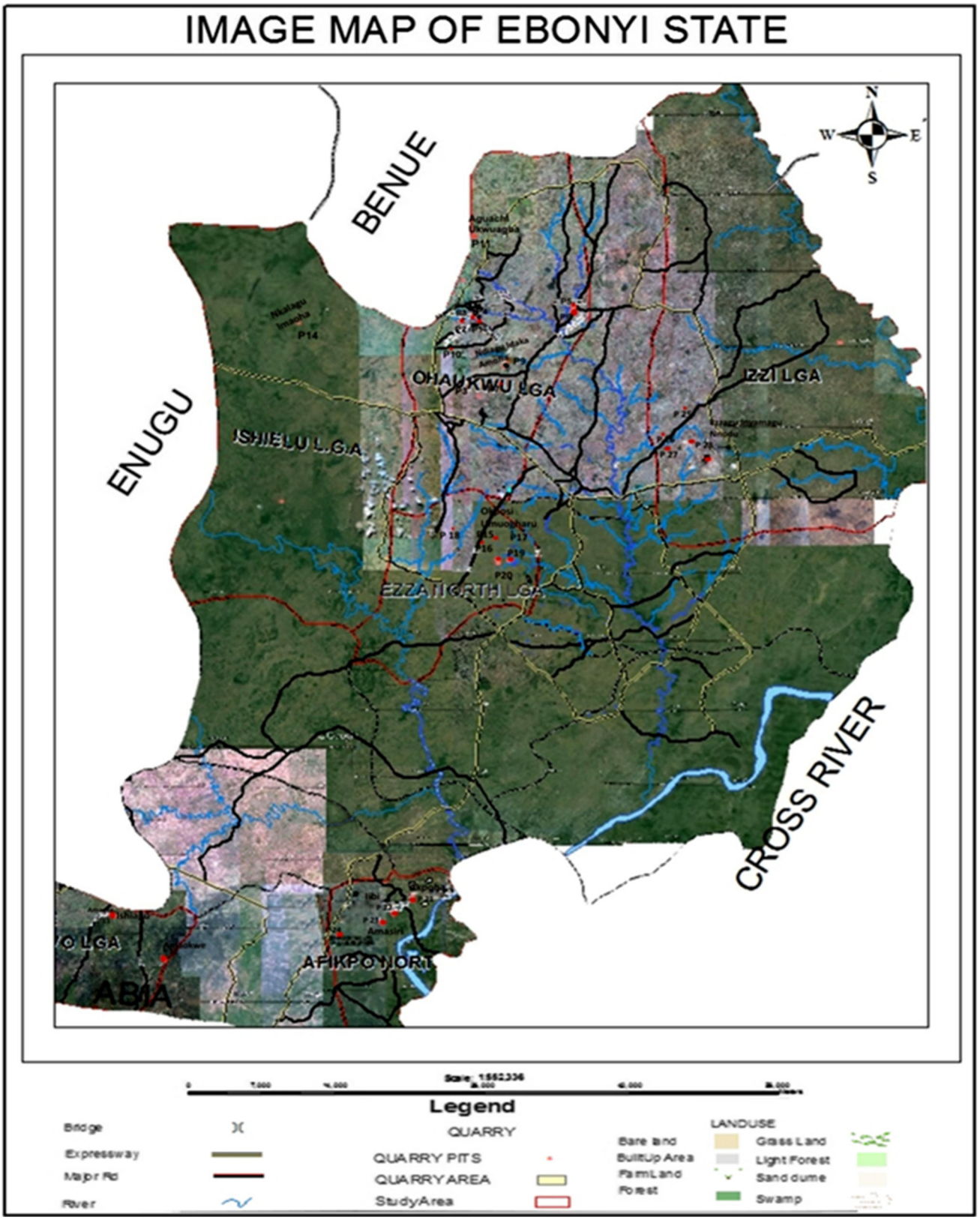

Fig. 4 Satellite imagery of Ebonyi State, 2016. *Source*: Inforgraph Consultants Nigeria Limited

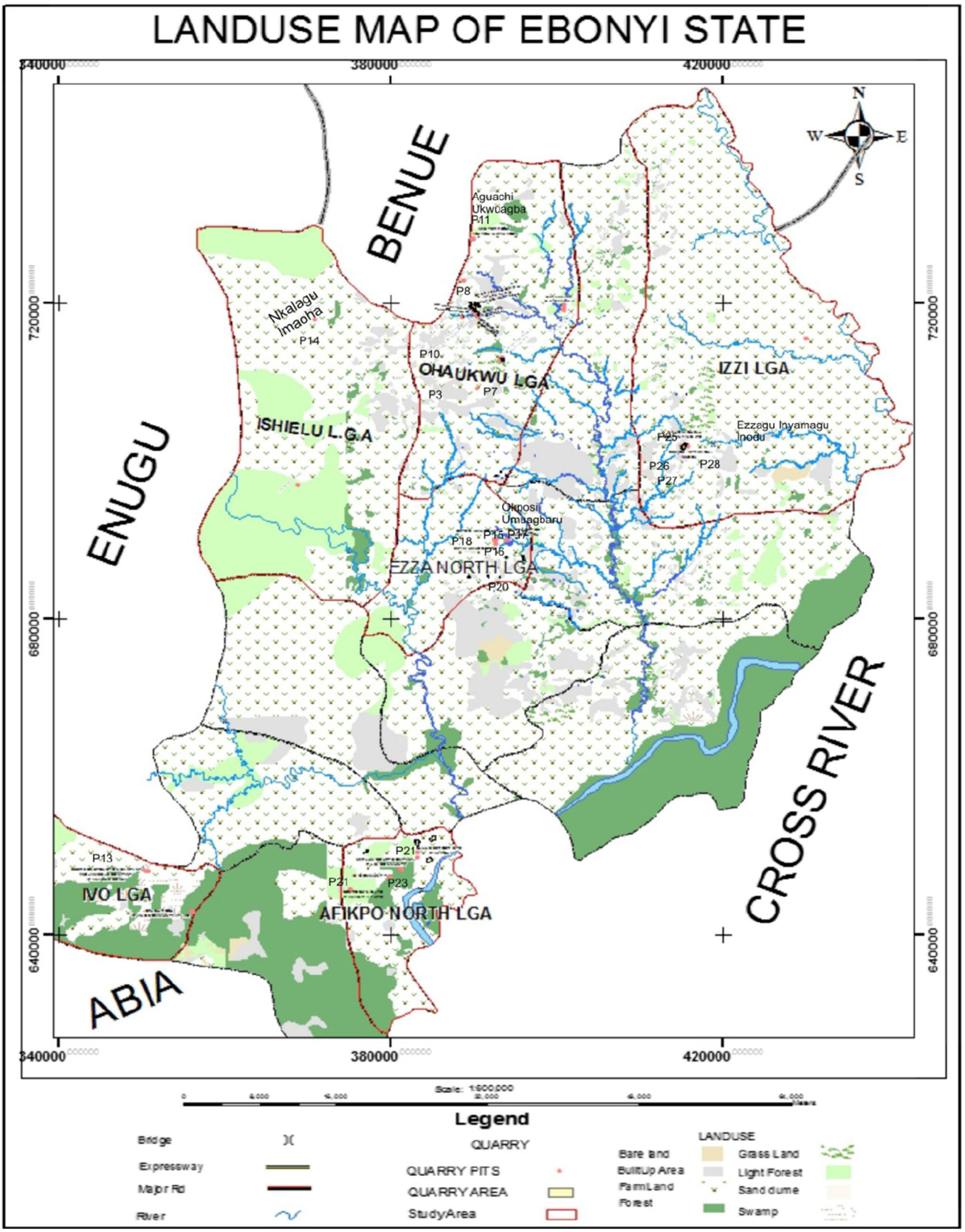

Fig. 5 Land use map of Ebonyi State. *Source*: Inforgraph Consultants Nigeria Limited 2015

Table 1 Statistical result of classified image for 2015 of land cover *Source*: Author's Fieldwork (2015)

N	Land use classes	Area (Sqm)	Percentage (%)
1	Urban/Built	1938.31	20
2	Agricultural crop land	1701.21	17
3	Forest/plantations	3123.69	32
4	Quarry pits	0011.00	0.1
5	Bare land surfaces	2977.47	30
6	Water bodies	22.96	1.2
	Total	9775.64	100

works on quarrying activities by Singh et al. (2000), Darwish et al. (2010), Knowles and Wareing (1999) and Oke and Ibanesebhur (2010), to mention a few, studied in other areas also confirmed the findings from this study that stone quarrying has a destructive effect on the green cover and environment.

The use of remotely sensed image provides data at a range of spatial, spectral and temporal scales. These data can be used by decision makers as informative and visual analytical tools in the order to monitor and determine the surface mining activities and their impacts on the

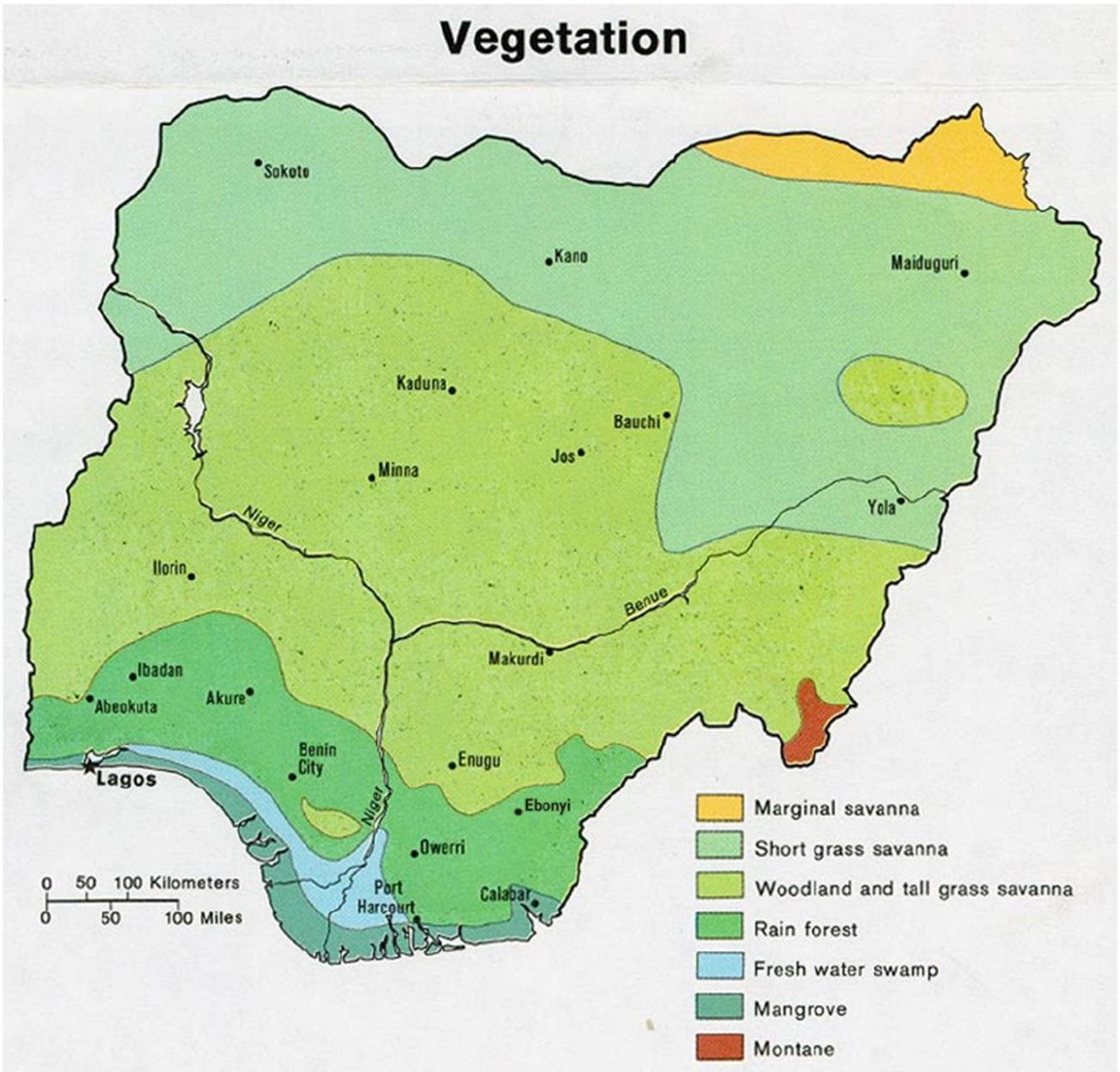

Fig. 6 Map of Nigeria showing the vegetation of Ebonyi State. *Source*: Google Map, 2015

Table 2 Percentage of excavated vegetation by quarrying activities *Source*: Author's Fieldwork (2015)

Active quarry LGA areas	Total area of vegetation lost by quarry pits (ha)	% of area occupied by the quarry pits (%)
Ohaukwu	115.705	28.7
Ishielu	37.7325	9.3
Ivo	142.2	35.2
Afikpo North	59.535	14.7
Ezza North	32.3825	8.0
Izzi	15.3	3.7
Total	402.855	100

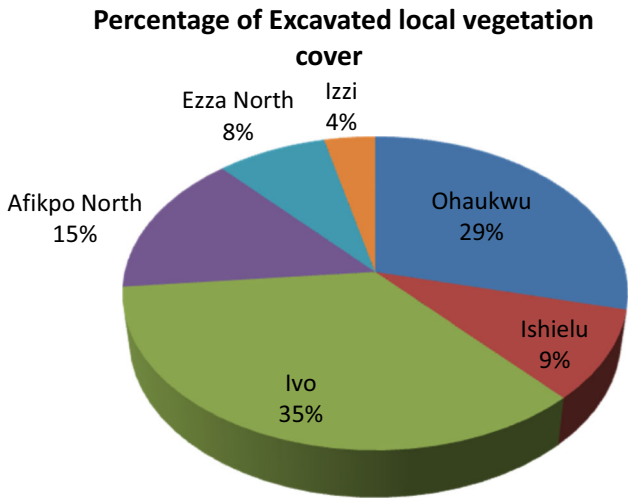

Fig. 7 Percentage of excavated vegetation cover in Ebonyi State. *Source*: Author's fieldwork, 2015

environment in a quick and cost-efficient way (Latifovica et al. 2004). Then, recording the distribution of land cover provides valuable information for improved management of land and vegetation (Saroglu et al. 2005). Hence, the visualization of remotely sensed data and its procession into well-designed maps are used as the best communication tools for studies of this nature that detects opencast mining areas (Schmidt and Glaesser 1998; Prakash and Gupta 1998; Wright and Stow 1999; Akanwa 2016).

Conclusion/recommendation

This paper presents a methodology to represent land uses through remote sensing data, GIS and field analyses. The analyses were supported by remote sensing data with (GeoEye of 1.0 m) high spatial resolution. The study showed that the State's vegetation resources have been analysed by the application of remotely sensed data in delineating areas destroyed by quarrying activities and the extent of green cover lost. The integration of satellite remote sensing data in GIS domain is a prerequisite in generating the base map of the study and hence delineating its land uses and basic features.

The study has been able to indicate and locate six LGAs and 27 active quarries where quarrying activities are intensified in the study area. Also, the study has been able to assess/classify six land uses in the area with quarry sites occupying 0.1% of the area. The study has determined that 402,855 ha of vegetation cover have been lost to quarrying in the area. Moreover, the various findings from the literature reviewed indicated similar findings with this study

Fig. 8 Excavated land area and vegetation loss in Amaeze Community

Fig. 9 Destroyed forest areas, deformed landscape and erosion menace at Nkalagu Area in Ebonyi State

Fig. 10 Waste particles of gravels are dumped into Iri-Ikpete stream at Ohaukwu. *Source*: Researcher's Fieldwork, 2015

(Howarth and Farber 2002; Kuzu et al. 2011; Sarma and Kushwaha 2006; Jiya and Musa 2012; Darwish et al. 2010; Anil and Katyar 2000).

However, based on these findings a sustainable quarrying action plan needs to be initiated to help in monitoring urban forest and green cover at regular intervals. Notably, the contribution of trees, grasses and vegetation in balancing carbon cycle is critical if climate change must be checked, habitat for floral and fauna must be preserved, biodiversity conserved, air pollutants absorbed and the extinction of plants and animal species monitored (Khera et al. 2009; Oke 1989; Bonan 2002; Nowark and Dwyer 2007).

Hence, the findings from this study will better equip government, urban planners and decision makers to incorporate it in national and urban planning and development programmes which will translate the research into ground action.

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