Global Scientific JOURNALS

GSJ: Volume 7, Issue 1, January 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

ASSESSMENT OF LAND DEGRADATION IN ABANDONED MINE SITE AT OKABA IN KOGI STATE OF NIGERA

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KeyWords
ASTER DEM, biophysical, degradation, indices, land, LULC, mine, and spectral

ABSTRACT

The aim of this study is to evaluate the status of land degradation in Okaba mine using geospatial techniques. The location of study is between latitudes 7˚ 25’ and 7˚ 31’N; and Longitudes 7˚ 40’ and 7˚ 46’ E, covering a land mass of approximately 171.08km^2. Remotely sensed data including Landsat (ETM+) of 2009 and ASTER DEM were used along with ancillary data to quantify five disparate categories of land degradation. This involved the computation of biophysical indices, supervised classification by maximum likelihood, and the computation of sediment transport index (STI). Land use/land cover (LULC) of the study area was actually determined in order to see the effects of land use on land degradation. Computed biophysical indices and the LULC were integrated to assess the degradation scenario in the study area using the spatial analyst module in ArcGIS 10.1 software. Five degradation categories selected for analysis includes: highly degraded, degraded, non-degraded, moderately degraded, and slightly degraded. The result reveals that, about 33% and 16% of the study area is highly degraded and degraded respectively. Also, 45.7% and 3.2% of the land is non-degraded and moderately degraded respectively, while, 0.4% is slightly degraded. The result further indicates that, bare land is the dominant land cover and the most degraded at 38.32km^2 while rock debris is the list degraded at 0.03km^2.

1. INTRODUCTION

Land degradation is one of the most significant problems in the contemporary society, as a result of its implication on agronomic productivity, the ecosystem, and food security. It is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land [1]. Land degradation encompasses the whole environment but includes individual factors concerning soils, water resources (surface, ground), forests, croplands and biodiversity [2]. It is viewed as any change or disturbance to the land perceived to be deleterious or undesirable [3]; and it is much more prevalent more or less in the underdeveloped and developing nations of the world. For example, land degradation in sub-Saharan Africa is pervasive, affecting 20-50% of land and over 200 million people. Land degradation is equally widespread and severe in Asia and Latin America. The immediate causes of land degradation are inappropriate land use that leads to degradation of soil, water, and vegetative cover and loss of both soil and vegetative biological diversity, affecting ecosystem structure and functions [4]. Simply, land degradation is mostly caused by anthropogenic factors. For instance, mining activities are among the major factors of land degradation especially in the developing nations. Of course, the rate at which mineral resources are used is constantly increasing with the advancement of science and technology, economic development, industrial expansion, population growth, as well as the acceleration of urbanization. Thus, human society and civilization heavily rely upon the mining industry to operate and maintain comfort, and the end result on earth's surface is mining wastes and alterations in landforms.

Mine wasteland usually encompasses the bare stripped area and loose soil piles, waste rock and overburden surface, subsided land area, as well as other degraded land by mining facilities, among which the waste rock frequently pose intense stressful conditions for restoration. Mining modifies the beauty of the landscape and also alters the soil components including soil horizons and structure, soil microbe populations, and nutrient cycle. The overburden dumps include: adverse factors such as elevated bioavailability of metals; elevated sand content; lack of moisture; increase compaction and relatively low organic matter content. Acidic dumps may release salt or contain sulphuric material, which can generate acid-mine-drainage [5]. The effects of mine wastes can be multiple, such as soil erosion, air and water pollution, toxicity, geo-environmental disaster, loss of biodiversity and ultimately loss of economic wealth [6],[7]. The process of mining causes adverse impact on land. For example, open cast mining scares the landscape, disrupts ecosystems and destroys microbial communities. The degraded land created in the aftermath of open cast mining often does not support biomass development. In essence, extensively mined land usually does not possess sufficient surface soil to anchor plants.

Generally, information about the alteration in landscape may be acquired by various means or techniques [8] including the conventional and advanced approaches. Studies on landscape change using traditional methods, like aerial photography and field survey are time consuming, and they do not provide a holistic picture of the study area. Conversely, the consciousness and deployment of the advanced technologies involving advanced computers, remote sensing, global positioning system (GPS), Geographic Information System (GIS), and the power of spatial information system dedicated towards decision making and resource management has increased globally [9]. Thus, the application of Geospatial Technology which integrates remote sensing, geographic information system and global positioning system is found to be time and cost effective approach to the assessment of natural resources [10].

Remote sensing has over the years proved to be an infinite pool of earth related data [11]. Satellite based remote sensing has emerged as an excellent tool for pre-survey, planning and monitoring of mining activity and for assessing its impact on land, water and air. Moreover, the growing potentials of Geographic Information Systems make it feasible for computer systems to handle geospatial data more efficiently than before [12]. A large number of studies have been carried out using different methods of remote sensing and geographic information system (GIS) to determine the extent of land degradation such as [13],[14],[15],[16]. The current study is a similar effort with specific interest in determining the status of degraded land in abandoned mine site at Okaba in Kogi State of Nigeria.

2. MATERIALS AND METHODS

2.1 STUDY AREA

The current study is located at Okaba in Ankpa Local Government Area of Kogi state, between latitudes 7˚ 25′ and 7˚ 31′N; and Longitudes 7˚ 40′ and 7˚ 46′E (Fig.1). It covers an area of approximately 171.08km^2. The area is made up of sand stones with shale, schist and low coal measures of the granite origin. It is also underlaid by igneous and sedimentary as basement complex. It is typified by a gentle slope on approximately 300 meters above the mean sea level at base of the escarpment. The soil of the study area which is predominantly deep and sandy is well drained resulting in a limited water holding capacity. Furthermore, the study area falls within woodland savannah characterized by shrubs, grasses, and discontinuous canopy.

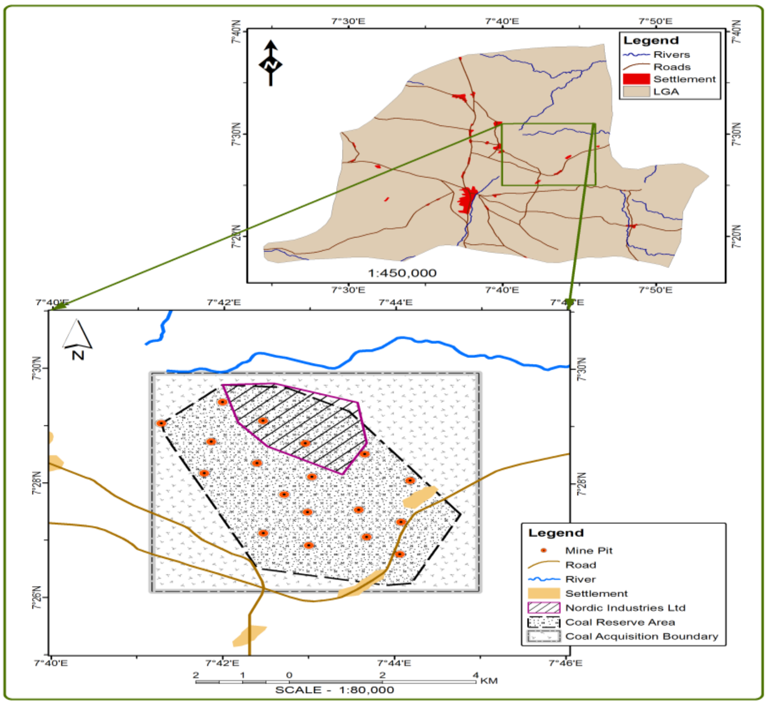

Fig. 1: Map of Ankpa (Top RHS) Showing the Study Area (Bottom LHS)

2.2 Data

Landsat Enhance Thematic Mapper Plus (ETM+) of 2009, and the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) with spatial resolution of 30m were used in the current study. Though, the ETM+ data of 2009 has an inherent problem as a result of the Scan Line Corrector (SLC) error, the error was however corrected using gap filing algorithm in the ILWIS 3.3 software.

2.3 Validation Studies

Ground survey was carried out to acquire information about various land use/land cover (LULC) and degraded land. We used satellite imagery, global positioning system and topographic maps to validate the generated geology, LULC and land degradation maps.

2.4. Image Preprocessing

The image scene and scanned topographic map were co-registered into UTM zone 32N, WGS 84 to bring them into the same coordinate system [9]. Also, atmospheric and radiometric corrections were carried out.

2.5. Computation of Biophysical Indices

NDVI was computed from the landsat image scene using raster calculator in ArcGIS 10.1 environment. Two images of the same scene, simultaneously acquired, concerning Near Infra-Red (NIR) and Red were used. The radiations correspond to bands 4 and 3 respectively for the ETM+ data. The NDVI was determined for the imagery using the following model:

$$NDVI = (NIR - RED) / (NIR - RED) \quad \ldots\ldots (1)$$

Where, NIR and RED are reflectance corresponding respectively to band 4 and band 3.

We know that, the sensor bands often respond in a strongly correlated manner to surface features, so analysing imagery using natural or false colour may not distinguish the surface features in an optimal fashion [17]. In order to overcome this problem, we thus applied Tasseled Cap Transformation (TCT) so as to transform the landsat bands into three indicators of known characteristics including soil brightness (TCB), vegetation greenness (TCG) and soil/vegetation wetness (TCW).Tasseled cap wetness is normally used to determine the amount of moisture being held by the vegetation or soil, thus termed wetness.

2.6. LULC Classification

Maximum Likelihood supervised classification technique was used for the LULC classification. First, the training sites for the study were identified and delineated. Training samples were collected from fieldwork [18]. This comprises bare land, built area, grassland, rock debris, and shrub. Also, the signature files which contain the statistical information about the reflectance values of the pixels within the training site for each of the five land use and cover types or classes was developed [19], for the actual supervised classification of the study area. The signatures served as impute into the supervised classification algorithm.

2.7. Mapping Sediment Transport Index

The ASTER DEM was used to establish the flow direction, which was in turn used for the determination of the flow accumulation. Subsequently, the compound index was computed from which the sediment transport index (STI) was determined using the following model:

$$STI= [(m+1) \times (A_s / 22.13)^{m} \times (\sin \beta/0.0896)^{n}] \quad \ldots\ldots (2)$$

Where, "As" is the flow accumulation, "β" is the slope, m = 0.4 and n = 1.3. It is noteworthy that, "As" determines how much water is accumulating from upstream areas and therefore identifies areas that contribute to overland flow.

3. Results and Discussion

3.4. Biophysical Indices Results

As indicated in figure 5, Tasseled Cap values were obtained for brightness, greenness, and wetness in the range of 002-255, 4.00-4.00, and 0.00-2.55 respectively. Also, the NDVI values ranges between -0.21 to 0.52. Generally, high values reveals moderate to high degradation, while low values shows slight degradation to non-degraded areas. Moreover, the result reveals that, the lower soil moisture give rise to lower vegetation cover.

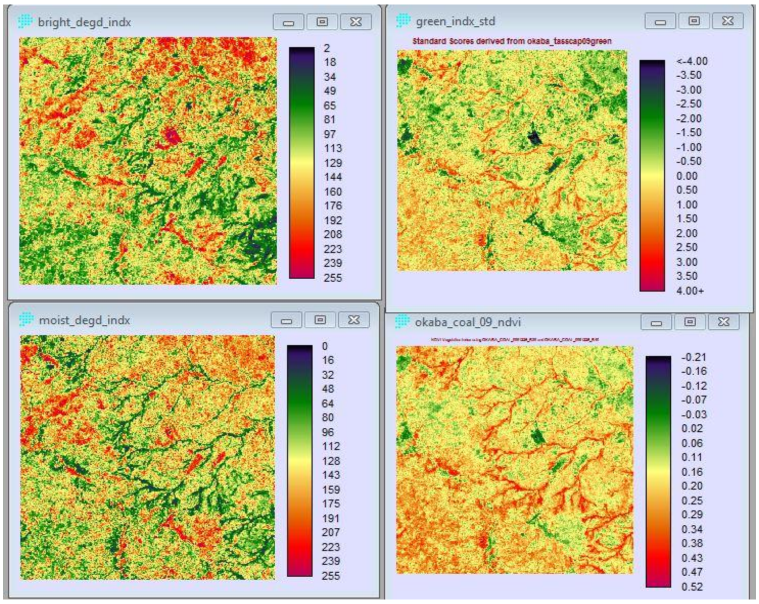

Fig. 5: Biophysical indices: Brightness (Upper LHS), Greenness (Upper RHS), Moisture (Bottom LHS) NDVI (Bottom RHS)

3.1. Land Use And Land Cover Classification Results

The statistics and map of LULC of the study area derived from the satellite imagery of 2009 are shown in table 1, and figure 2 respectively. Both the table and map depicts five LULC including bare land, built area, grassland, rock debris, and shrubs.

Table 1: Areal extent of LULC type of the study area in 2009

Object ID	LULC	Area (KM^2)	% Area
1	Bare land	60.16	35.2
2	Built area	13.52	7.9
3	Grassland	58.94	34.4
4	Rock debris	17.45	10.2
5	Shrubs	21.01	12.3
	Total	**171.08**	**100**

The information in table 1 shows that, bare land occupies 60.16km^2 (35.2%) of the total land area, and is the predominant land use class that is under land degradation due to intensive anthropogenic activities. Built area covers 13.52km^2 (7.9%) of the total area of land in the study area. Grassland occupies 58.94km^2 (34.4%) of the total land area. Rock debris covers 17.45km^2 (10.2%) of the total land area. Shrubs occupies 21.01 (12.3%) of the total land area. The vegetation in the grassland and shrubs in this study represents sparse vegetation which is a sign of degraded environment.

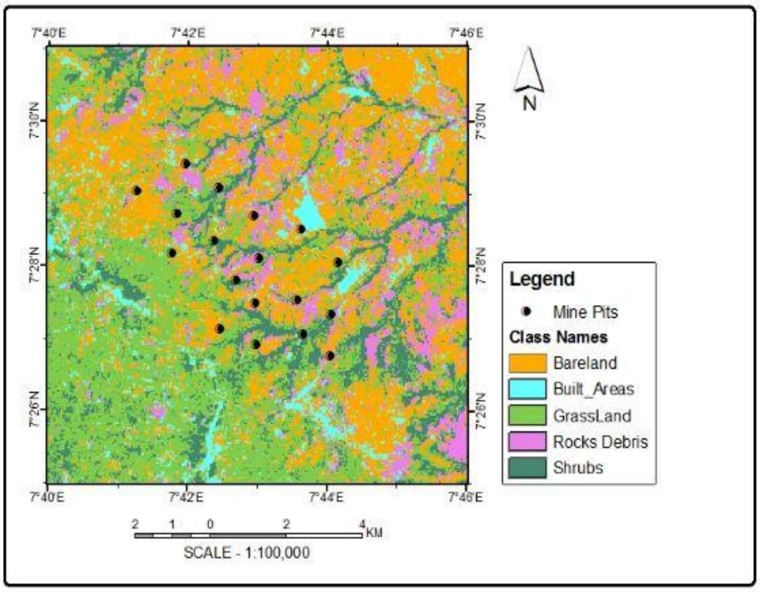

Fig. 2: 2009 LULC map of Okaba

From figure 2, it is apparent that, the scattered shrubs, rock debris as well as bare land represent a degraded landscape. Of course, mining and agricultural activities could have brought deforestation and soil erosion that have caused damage to the native vegetation structure. Therefore, the observed land cover types may be as a result of varying degree of human intrusion on the native vegetation. In this research, Landsat ETM+ data has distinguished major land cover types, which is consistent with the capability of Landsat ETM+ data demonstrated elsewhere for mapping and monitoring land cover of environmentally degraded landscapes such as [20].

3.2 Sediment Transport Index Result

In this study, hydrologic indices based on the flow accumulation, and linked to the drainage system analysis demonstrate the potential of STI, to model flood impact on land erosion and degradation, and sediment accumulation. We used STI to predict the severity of soil erosion. Soil erosion potential increases with increase in sediment transport index. Figure 4 shows the STI-derived map with values varying between 0.06-2656.91. It illustrates the spatial distribution of the sediment transport capacity and accumulation. Higher values were found in hilly areas. A high STI value indicates area of active gully erosion. Spatial pattern of STI can be used for identifying erosion prone area and to suggest suitable soil conservation measures taking into account the land cover in the study area. These areas are associated with a significant degree of sediment transportation and, consequently, significant soil erosion and degradation. Of course, this index shows the increased erosivity of channel flow in the downstream, and sediment deposition in the plain.

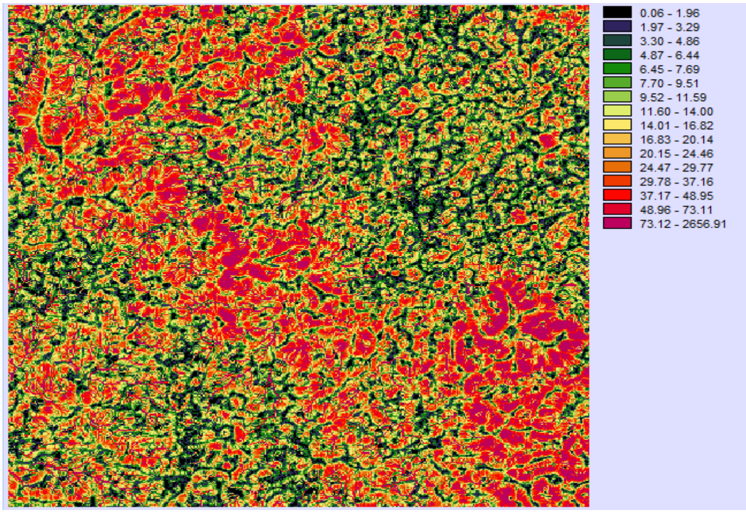

Fig. 4: Sediment transport index map of the study area

3.5. Land Degradation Classification Results

Information on NDVI, STI and TCT were integrated for subsequent analysis. This was followed by the assignment of weight and class ranks to each variable. High ranks were assigned to areas with low values as an indication for land degradation, while low ranks were assigned to areas with higher for non-degradation. The result is a land degradation map depicting mine pits, and degradation categories (figure 6), as well as estimates (table 2).

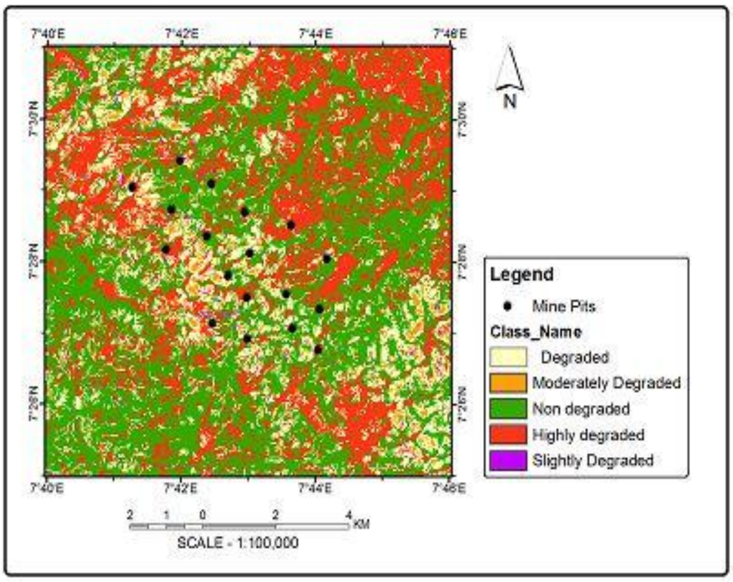

Fig. 6: Map depicting the status of land degradation in the study area

Table 2: Areal extent of land degradation in the study area

Category	Area (KM^2)	% Area
Highly degraded	57.46	33.59
Degraded	29.50	17.24
Non-degraded	77.49	45.30
Moderately degraded	5.72	3.34
Slightly degraded	0.91	0.53
Total	**171.08**	**100**

The result obtained as shown in table 2 reveals that, 57.46km^2 (33.59%) of the area of study is highly degraded; 29.50km^2 (17.24%) of the land is degraded; and 77.49km^2 (45.30%) of the land is non-degraded. Also, 5.72km^2 (3.34%) of the total area is moderately degraded; and 0.91km^2 (0.53%) of the total land area is slightly degraded.

Table 3: Areal extent of land degradation per LULC in the study area

Category	Bare land (Km^2)	Built area (Km^2)	Grass land (Km^2)	Rocks Debris (Km^2)	Shrubs (Km^2)
Highly degraded	38.32	9.25	9.59	0.03	0.27
Degraded	9.60	1.50	9.70	4.10	4.60
Non-degraded	10.64	2.47	37.37	12.48	14.53
Moderately degraded	1.45	0.25	1.96	0.82	1.24
Slightly degraded	0.15	0.05	0.32	0.02	0.37
Total	**60.16**	**13.52**	**58.94**	**17.45**	**21.01**

Table 3 shows that, bare land is the most degraded among the land use/land cover classes in the study area. This could be attributed to the effects of mining activities which leads to loss of vegetation cover and increase soil erosion, making the soil infertile to anchor plants. The pictorial representation of the statistics in table 3 is shown in figure 7 in which the vertical axis indicates the area (km^2) of land, while the horizontal axis shows the LULC. Also, the lines represent the categories of land degradation.

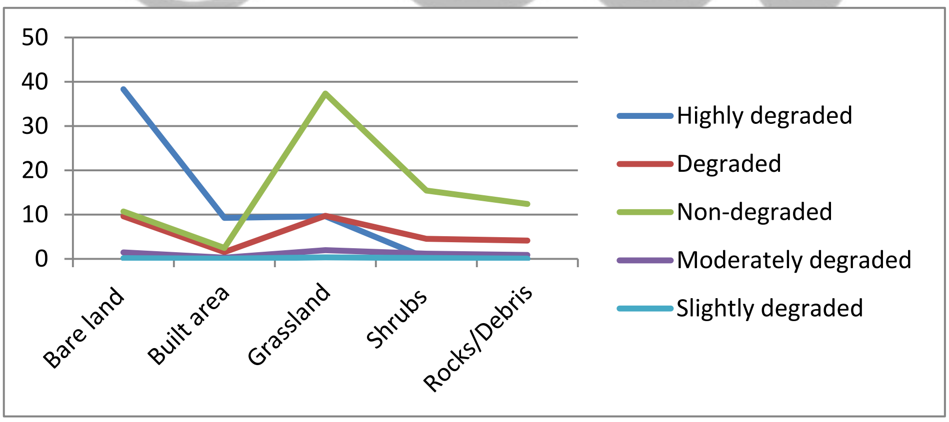

Fig. 7: Line graph showing the categories of degraded land in the study area with respect to LULC and their area in km^2.

4. Conclusion

In this study, we implemented five essential indicators of land degradation, which combines the satellite-based estimates of LULC and spectral indices of vegetation, soil, moisture, as well as erosion potential. We then defined the areas where the indicators are affected by land degradation or prime targets for land degradation. Of course, the maximum likelihood supervised classification leads to the homogeneous units of dynamic response to degradation processes. The results obtained show that, bare land is the dominant land cover and the most degraded. Additionally, this study indicates that, the intensity of degradation increases with distance from the abandoned mine pits, and severe land degradation affects a significant portion of the arable land.

Finally, this study has demonstrated the effectiveness of geospatial techniques in the identification, and assessment of degraded land. This is evidenced by the estimates and mapping results of the spatial extent of various categories of degraded land in the area of study. Certainly, the synergy of this derived information from Landsat and ASTER DEM allows the robustness of land degradation process modelling and analysis. In addition, the application of remote sensing and GIS is clearly a very efficient and cost effective way of degradation management.

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