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Assessment of Terrain and Land Use/Land Cover Changes of Mine Sites using Geospatial Techniques in Plateau State, Nigeria

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Abstract

In this paper, we report a geospatial assessment of the selected mine sites in the Plateau State, Nigeria. The aim of this work is to determine the impact of mining on the terrain as well as the Land Use/Land Cover (LULC) of the host communities. The Shuttle Radar Topographic Mission (SRTM) is used for the terrain mapping. The derived impact of mining on LULC between 1975 and 2014 is determined by classifying the relevant Landsat imageries. The digital terrain map reveal that the mining activity is not well-coordinated. Hence, the parts of the mine sites that are rich in the desired minerals are punctuated with low depth, while the other parts have high terrain as a result of the haphazard mining activity. The analysis of the LULC change show that the degraded land (DL), built-up area (BU), water bodies (WB), and exposed rock outcrop (RO) increase by 15.68%, 4.68%, 0.06%, and 14.5%, respectively, whereas the arable farmland (FL) and forest reserve (FR) decrease by 28.29% and 6.63%, respectively. Mining has adversely affected the natural ecology of the studied area. Therefore, the mine sites should be monitored, and their environmental damages should be pre-determined and mitigated. There should be regular inspections to keep these activities under control. The existing laws and regulations to conserve the natural ecosystems of the host communities should be enforced to curtail the excesses of the operators of the mining industries. Restoration of the minefields to reduce the existing hazards prevent further environmental degradation, and facilitating the socio-economic development of the area is also suggested.

1. Introduction

Mining is an important component of the economy of many nations, especially the developing countries. However, it could cause untold environmental degradation [1-4]. Mining activities should, therefore, be responsibly coordinated and monitored. In addition, best practices must be put in place in order to avoid the attendant devastating consequences of the uncoordinated mining. The environmental impact of mineral extraction includes air, land, and water pollution, damage to vegetation, ecological disturbance, degradation of the natural landscape, radiation hazards, geological hazards, and socio-economic problems [5]. The open-pit mining method, which was used in the studied site like many other mines in developing nations, could have a devastating effect on the human lives and the ecosystem [6, 7].

Open-pit mining is known to degrade the mine environment, primarily because the native vegetation and protective soil cover are removed as a first step. Thus the arable land is lost [8]. The concentration of mining activities in an area can lead to a rapid degradation with serious economic effects including the loss of agricultural lands [1]. The natural landscape is usually replaced by degraded land or hummock topography punctuated by irregular holes [9, 10]. Ndace and Danladi [11] have opined that this can greatly disfigure the host communities of the mining sites.

The ecosystem is disturbed by the mining activities. Mineral extraction usually destroys the

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natural landscape, creating open spaces in the ground and generating heaps of waste rocks that cannot be easily disposed off. The elements of land degradation such as soil erosion, deforestation, and loss of bio-diversity are common occurrences in the mining communities [12, 13]. The deforestation of an area during mining operations, for example, may cause the elimination of some plants and exodus of some animals and birds that feed on such plants or depend on them for cover.

The conflict between the mining activities and the environmental protection has intensified over the years. Therefore, the quantification of the effects that the mining activities have on ecosystems is a major issue in sustainable development and resource management. The benefits of resource exploitation should be balanced against the environmental degradation. This must include quantitative assessment and prediction of such impacts on the environment.

The remote sensing data that can be used to map the alteration of minerals [14, 15] is also a reliable tool to assess the extent and environmental impacts of the mining activities on landscapes. It could also be used to monitor changes in land use. While remote sensing can be used to map the spatial patterns and rates of land use/land cover change, relating these changes to a suite of environmental and socio-economic activities is necessary in order to understand the consequences of land use change for local livelihoods [16-18].

Remote sensing is increasingly becoming an important tool for monitoring different aspects of ecosystems at local, regional, and global scales. However, it is under-utilized in the mining sector. In addition to being the only available data source in remote areas, the benefit of acquiring data with sufficient area coverage and temporal frequency for studying and monitoring the primary impacts caused by surface mining at low cost put it ahead of any other of monitoring the ecosystem.

Land use and land cover are distinct yet closely related. Land cover refers to the type of vegetation cover as well as human structures, soil type, bio-diversity, surface and ground water but land use is the foundation of all forms of human activities [19]. Lambin *et al*. [20] have defined sustainable resource use as the use of environmental resources so that future human needs can be met from the natural resource base. Changes in LULC have global effects and must be monitored [21, 22]. Exploitation of mineral resources can change the LULC patterns of the host communities.

Remote sensing has been a useful tool in environmental research works. Land-use and land-cover change (LULCC) is a major driver of the global change through its effects on the climate, ecosystem processes, biogeochemical cycles, and bio-diversity [23] as well as improvements in the spatial information technology to assess and monitor the earth surface [19]. Therefore, the analysis of LULCC has become an important component of the ecosystem research works. The spatial configuration of land use is a reflection of the activities of different land users and managers. It is essential to link the patterns of land-cover change to the underlying activities and processes so as to better understand the mechanisms of change, generate predictions about future rates, and vulnerable places to change, and design appropriate policy responses to change [24].

The objective of this work was to carry out an in-depth assessment of landscape change in a 1523 km^2 area in the Plateau State, Nigeria. The continual change in land covers offers additional information concerning the vulnerability of land covers to transition to other classes.

Although mining contributes to the economic development of host communities, it could also also cause deforestation, loss of fauna, washing away topsoil, and loss of cultural heritage and farm land. Open-pit mining of cassiterite and columbite in Jos environs denuded the landscape [25]. In fact, the structural developmental activities in most parts are difficult and costly due to the undulating nature of the terrain. The abandoned and un-reclaimed mine sites also produce erosional features like canyon, mesa-buttes, and residual hollows [26-28]. The area is no longer beautiful due to the mounds of mine waste and tailings and the associated erosion. This has reduced the tourism potential of the state. Therefore, in this work, we evaluated the impact of mining on LULC of the Jos area, Plateau State, Nigeria. Digital terrain maps of the studied area using the Shuttle Radar Topographic Mission (SRTM) imagery were also produced.

2. Materials and methods

2.1. Description of Studied Site

The studied area is located within the Naraguta topographical sheets of the Plateau State, Nigeria. It lies between the latitudes 9° 30’N and 10° 00’ N, and stretches longitude 8° 45’ E and 9° 00’ E, and covers an area of about 1,523 km^2. It is in the Guinea savannah ecosystem of the northcentral region of Nigeria. Most of the dwellers of the studied area are engaged in mining and farming as the primary occupation. There is a large concentration of population in the studied area due to its strategic importance as an administrative center in providing employments to people aside mining and farming. The studied area has steep escarpment edges with a descent of about 600 m to the surrounding plains. It has an average elevation of about 1200 m above the mean sea level, rising to 1777 m above the mean sea level around the Jos-Shere hill [29]. It is characterised by impressive ridges and rocky hills. Jos has exhibited a variety of land forms possessing a beautiful landscape that provides excellent picnic resorts, and is attractive to lovers of nature despite its damaged condition. The studied site has been described as a "disasterous area" due to the indiscriminate mining activities in the past [30].

The mine sites were selected from the Rayfield, Gero, Sabongida Kanar, Kuru Jantar, Bisichi, and Barkin Ladi communities. The Bisichi and Barkinladi communities are located in the Barkinladi Local Government Area. The other communities are located in the Jos South Local Government Area. Table 1 shows the geographical coordinates of the selected mine sites.

Table 1. Geographical coordinates of selected mine sites in the studied area.

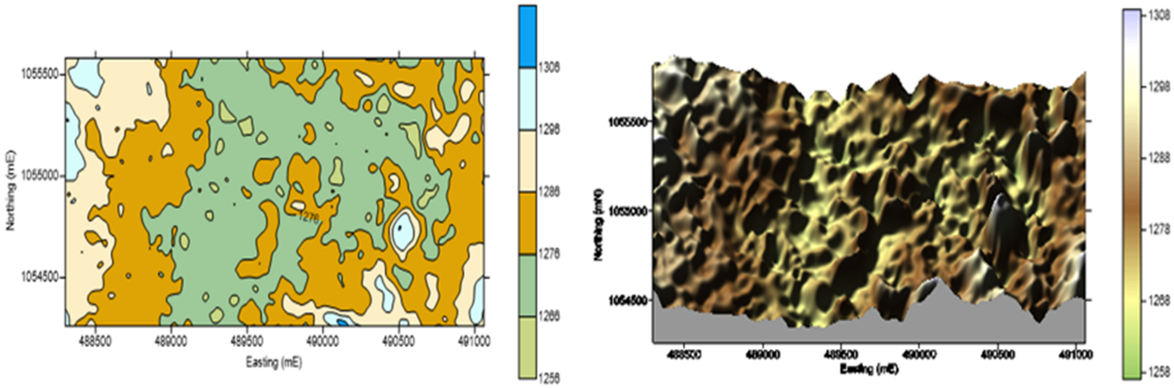
Mine site	Longitude (E)	Latitude (N)
Rayfield	E 08° 54.441' to E 08° 54.84'	N 09° 50.049' to N 09° 49.682'
Gero	E 08° 49.012' to E 08° 49.033'	N 09° 49.081' to N 09° 49.154'
Sabongida Kanar	E 08° 48.495' to E 08° 48.699'	N 09° 47.081' to N 09° 47.241'
Kuru Jantar	E 08° 52.117' to E 08° 52.284'	N 09° 41.548' to N 09° 41.747'
Bisichi	E 08° 55.357' to E 08° 55.581'	N 09° 41.605' to N 09° 41. 763'
Barkin Ladi	E 08° 54.089' to E 08° 54.229'	N 09° 32.168' to N 09° 32.553'

2.2. Geology

The geology of the studied area is that of the Younger Granite series that intrude the Basement complex with the lithologic units (Older Granite, Younger Granite, Volcanic, Magmatic Gneiss Complex, and Sedimentary Basin) emplaced during the Jurassic era. The Younger Granite that is acknowledged for hosting the richest and also the most extensive alluvial deposits of cassiterite and columbite in Nigeria are shed from the biotitic–granite of the studied area [31]. The Younger Granite is the source of economic quantities of tantalite, cassiterite, columbite, zircon, monazite, ilmenite, thorite, molybdenite, and pyrochlore [32]. Tantalite, cassiterite, and columbite mining, mostly from alluvial deposits, and processing the ores have been taking place for over a hundred years on the Jos-Plateau, Nigeria [33]. This must have had a devastating effect on the landscape [34].

2.3. Production of Digital Terrain Map

Digital Terrain Map (DTM) was used to extract the vital topographic information [35, 36]. In order to assess the change in the terrain of the studied area, a DTM of the studied area was produced using the Shuttle Radar Topographic mission (SRTM); it is believed to provide one of the most complete and highest resolution DTM of the Earth [37]. The Shuttle Radar Topography Mission (SRTM) 30 m DEM of the studied area was obtained from the United States Geological Survey/National Aeronautics and Space Administration/Shuttle Radar Topography Mission (USGS/NASA SRTM) [38]. The terrain maps of the studied area were produced by navigating the earth explorer website. The coordinates of the edges of the studied area were clipped, and the data set type (SRTM) was picked from the digital elevation menu. The SRTM image of the studied area produced was then downloaded and imported to the Surfer environment, where it was gridded, mosaicked, and trackballed to produce the contour map (Figure 1a), which was afterward 3-D wire framed to obtain a 3-D Digital Terrain Image (Figure 1b).



(a) (b)

Figure 1. a) Contour map and b) Digital terrain image.

2.4. Evaluation of Impact of Mining on Land Use/Land Cover

In this work, we employed a Multi-spectral Scanner (MSS) of 1975: a Landsat Thematic Mapper (TM) of 1988, an Enhanced Thematic Mapper Plus (ETM+) of 2001, and an Operational Land Imager (OLI) of 2014 (all at a resolution of 30 m) in order to assess the impact of the mining activities on the studied area. The Cloud–free Landsat imageries covering the studied area (paths 188, rows 053 of the worldwide reference system) with a spatial resolution of 30 × 30 m were obtained from the archives of the United States Geological Survey (USGS) (Table 2) in order to assess the impact of the mining activities on the studied area.

Table 2. Summary of landsat images acquired for the research work.

S/No	Landsat sattelite	Date	Path/Row
1	Landsat 4 (MSS)	5 Dec, 1975	188/053
2.	Landsat 5 (TM)	18 Dec., 1988	188/053
3.	Landsat 7 (ETM+)	2 Nov., 2001	188/053
4.	Landsat 8 (OLI)	8 Dec., 2014	188/053

The training datasets for each class were obtained using a combination of field site visits, maps, and aerial photographs. In order to ensure the spatial and temporal comparability of the datasets, the image pre-processing including the geometric and atmospheric corrections was performed in the Geographic Information System (GIS) environment [39]. The data was then pre-processed in ArcMap 10.5 for clipping/extracting and sub-setting of the image on the basis of Area of Interest (AOI). Table 3 shows a list of the Landsat images acquired and their dates. Four Landsat Imageries were downloaded from the USGS Glovis website (2011). A time series analysis of Multi-Spectra Scanner (MSS) satellite imagery of 1975, Thematic Manager (TM) of 1988, Enhanced Thematic Manager plus (ETM^{+}) of 2001, and Operational Land Imager (OLI) of 2014 was carried out. A supervised classification of the aforementioned land-cover classification was carried out using the supervised maximum likelihood algorithm. The training samples were obtained from the existing aerial photos and field surveys. The training and validation samples were limited to the areas that did not experience a change between the dates of remote sensing data and field surveys [40]. The downloaded landsat imageries were subsequently geo-referenced and clipped in the ArcGIS 10.5 software to delineate the boundary of the studied area. The images were enhanced, stacked, and masked before exporting to the ENVI 4.8 software for image classification and analysis. False colour composite (432 for 1975, 1988, 2001, and 543 for 2014) was prepared to reveal the spectral properties of the different urban land-use (mining area) and land-cover. The training site samples were collected for supervised classification of the studied area to highlight the different LULC viz: inland water bodies, thick forest, light forest, cultivated land, built-up, and mining area. A change detection analysis with the ENVI software was carried out to show the trend of change between 1975 and 2014. This was done to reveal the direction and magnitude of the effect of mining on the different land uses and cover of the studied area. The main land covers within the studied area were identified with the aid of a reference map. The classes identified were the inland water, forest, built-up, cultivated land, degraded land, and rock outcrop. The training areas were established by choosing one or more polygons for each class. The pixels that fell within the training area were taken to be the training pixels for a particular class. In order to select a good training area for a class, the important properties taken into consideration were its uniformity and how well they represented the same class throughout the whole image [41]. For each class, the training pixels provided values from which the mean and covariances of the spectral bands used were estimated. This information was used to assign the pixels to each class. The outcome of ML classification after assigning the classes with suitable colours is shown on the classified map of the studied area (Figure 2): inland water (blue), forest (thick green), built-up (yellow), cultivated land (light green), degraded land (orange), and rock outcrop (purple). The proportion of the land-cover (c_i) that was occupied by a given class i in a given year (1975, 1988, 2001 or 2014) was estimated using Equation 1:

$$Ci+=\sum_{i=1}^{n} Cij \quad (1)$$

where n is the total number of classes.

2.4.1. Accuracy Assessment

The classification accuracy signifies the degree of agreement between the remote sensing data and the reference information [42]. The human error, digitizing, lack of knowledge of the studied area, and other factors all contribute to inaccurate results in the supervised classification method [43]. An accuracy assessment of the individual classification is important in assessing the practicality of the classified data in the change analysis detection [44]. The accuracy assessment for the LULC maps of the Jos area field survey was performed digitally with ENVI 4.8 by creating an error matrix, which was the most common way of computing the accuracy assessment for any remote sensing application in image classification [45]. The accuracy assessment was carried out using the ground truth points based on the ground truth data collected during the fieldwork, high-resolution Google Earth images, and visual interpretation [46]. The error matrices that were the most efficient way of computing the accuracy assessment for any remote sensing application in image classification [47] were applied in the statistical comparison of the reference data and classification results. The error matrices were generated to assess the user's accuracy, producer's accuracy, and overall classification accuracy. The original pixel training samples were processed and analyzed using the Signature Editor on ENVI 4.8 before creating the error matrix so that the comparison between two error matrices from two successive classifications could be justified. This also ensures the credibility of the accuracy assessment. The next sections concern the overall accuracy for the years under study in the area. The standard error matrices were generated to assess the user's accuracy, producer's accuracy, and overall classification accuracy using the data from the output map as the rows and the reference data (ground truth points) as the columns in the matrices [47]. The accuracy assessment of the classification was determined by means of error matrix (otherwise known as the confusion matrix), which compared, on a class-by-class basis, the relationship between the reference data (ground truth) and the corresponding results of a classification [48]. Such matrices are square, with the number of rows and columns equal to the number of classes, i.e. 6. A measure of the overall behaviour of the classification was determined by the overall accuracy, which was the total percentage of the pixels correctly classified.

3. Results and discussion

3.1. Digital terrain map of studied area

Figures 3a to 3f display the digital terrain maps using SRTM 2014; the varying heights of the studied area are shown. The points on the Rayfield mine site vary in height between 1270 m and 1325 m with the mining activity concentrated around the western part of the mine site; hence, their low heights are as shown on Figure 3a. The perimeter of the studied area had a high land terrain with steepness down its respective centres. The points on the Gero mine site shown in Figure 3b vary in height between 1188 m and 1222 m. The mining activities were concentrated around the western part of the mine site. The perimeter of the studied area had a high land-terrain with steepness down its respective centres. The points on the Sabongida Kanar mine site vary in height from 1170 m to 1206 m, as shown in Figure 3c. The mining activities were concentrated around the northern part of the mine site, leading to reduction in their heights. The perimeter of the studied area had a high land-terrain with steepness down its respective centres. The points on the Kuru Jantar mine site (Figure 3d) vary in height between 1236 m and 1274 m. The mining activities were concentrated around the central and eastern parts of the mine site, resulting in their low heights. The perimeter of the studied area had a high land-terrain with steepness down its respective centres.

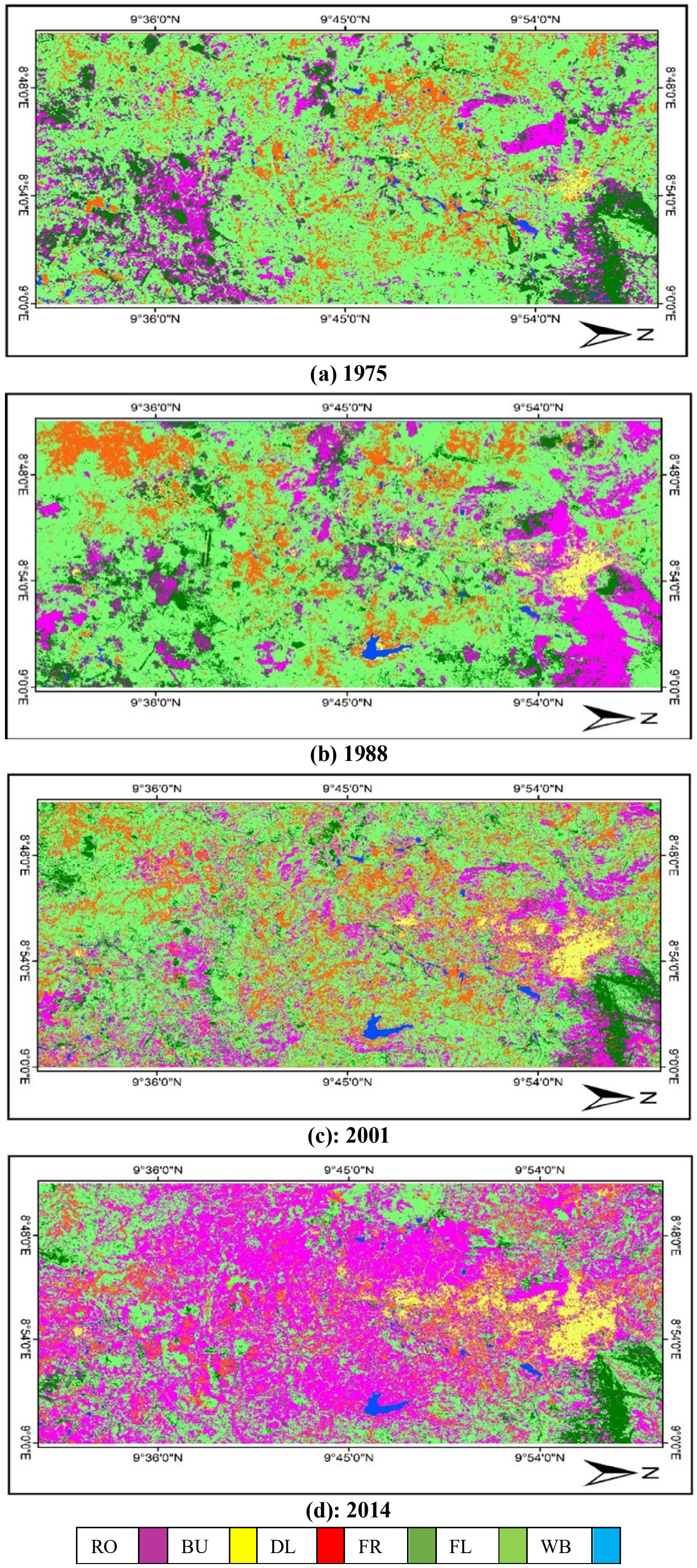


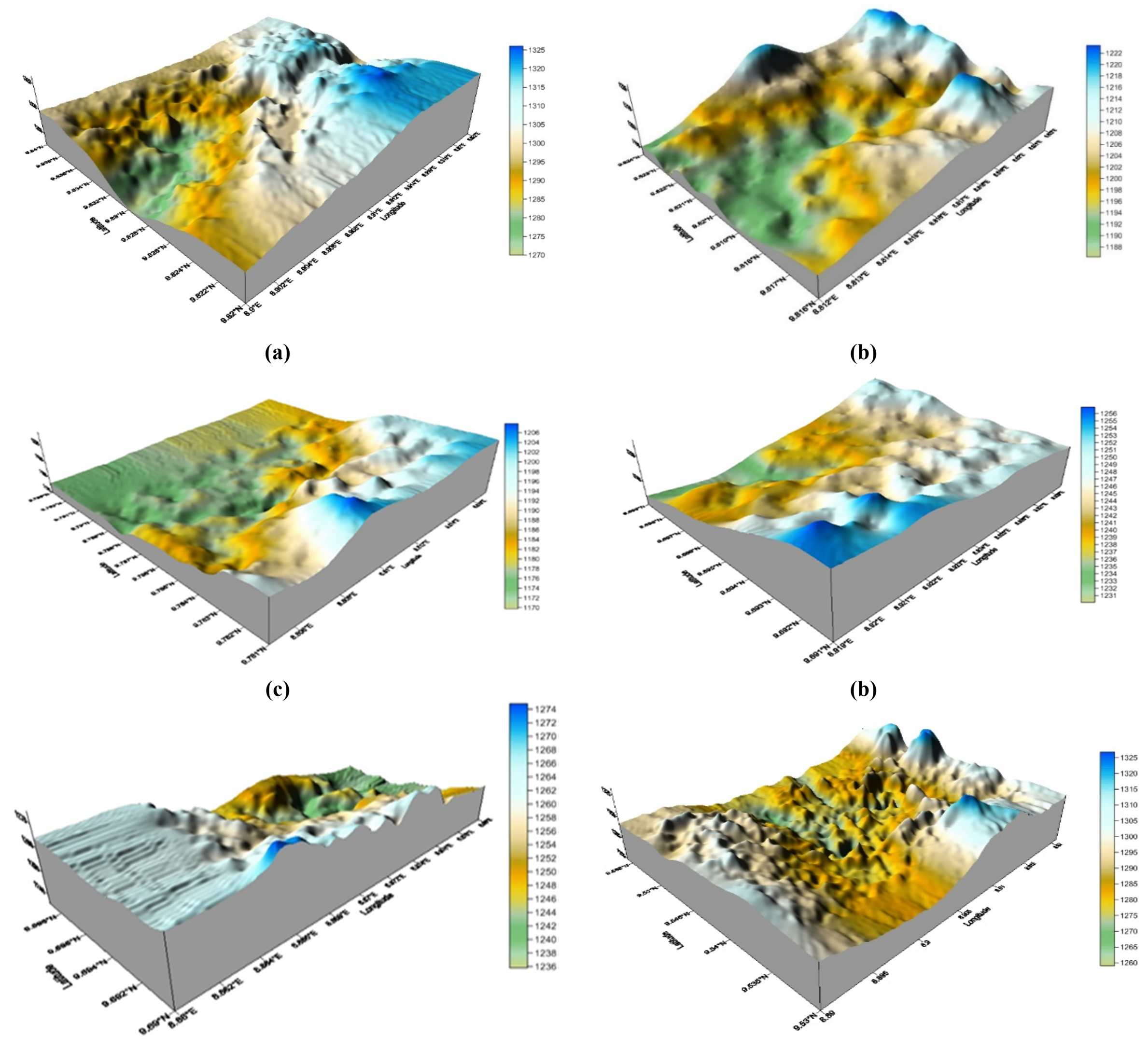
Figure 2. Classified maps of the studied area for the periods, a) 1975, b)1988, c) 2001 and d) 2014.

The points on the Bisichi mine site vary in height between 1231 m and 1256 m, as shown in Figure 3e. The mining activities were concentrated around the north-western part of the mine site with consequence in its low heights. The perimeter of the study had a high land-terrain with steepness down its respective centres. The points on the Barkin Ladi mine site, shown in Figure 3f, vary in height between 1260 m and 1325 m. The mining activities were concentrated around the central part of the mine site, thereby causing lowering of their heights. The perimeter of the studied area had a high land-terrain with steepness down its respective centres.

Land degradation and topographic changes, as seen in Figure 3 (a-f), are usually accompanied by weathering and erosion [49-51]. This could lead to erosion. The landscape in Jos is stable and has some vegetation. However, for trenching and pitting, the techniques used adversely affected the landscape [5]. This could further enhance flooding within the studied area. The problem of flooding must be addressed as it ends with a loss of important components of the ecosystem such washing away of the top soil, loss of arable farmland, and gully erosion to mention a few. All these are experienced in the studied area.

There were several abandoned mine ponds and mine spoils in the mine sites. Hence, the landscape of the studied area contains lots of dangerous mine ponds that have further degraded the area and pose imminent danger to both the human and animal lives.

The mined pits left unfilled render the land unsuitable for any purpose and become repositories for unwholesome water resulting in breeding grounds for malaria-infected mosquitoes that pose a significant threat to both the human and animal lives.



(a) (b)

(c) (b)

(d) (e)

Figure 3. Digital terrain map of the studied area: a) Rayfield, b) Gero, c) Sabongida Kanar, d) Kuru Jantar, e) Bisichi and f) Barkin Ladi mine sites.

3.2. Derived Impact of Mining Activities on Landuse/Landcover in Studied Area

The classified maps of the studied area for the four periods of 1975, 1988, 2001, and 2014 is presented in Figure 2. It was generated from the supervised classification of the satellite images. It was categorized into six classes, i.e. degraded land (DL), built-up area (BU), water bodies (WB), exposed rock outcrop (RO), arable farmland (FL), and forest reserve (RO). The data obtained through the analysis of multi-temporal satellite imageries is diagrammatically illustrated in Figure 4. The classified data was subjected to the accuracy assessment. The producer's accuracy, user's accuracy, and overall accuracy were calculated for the imageries by generating the error matrices (Tables 3-6). The ML classification yielded the overall accuracies of 98.55 %, 94.05%, 91.55%, and 95.85% for the studied period of 1975, 1988, 2001, and 2014, respectively (Tables 3-6). The results obtained indicated a very high agreement with the ground truth as the minimum acceptable overall accuracy was 85% [52]. It also conforms with the standard accuracy of > 90% for the LULC mapping studies recommended by Lea and Curtis [53].

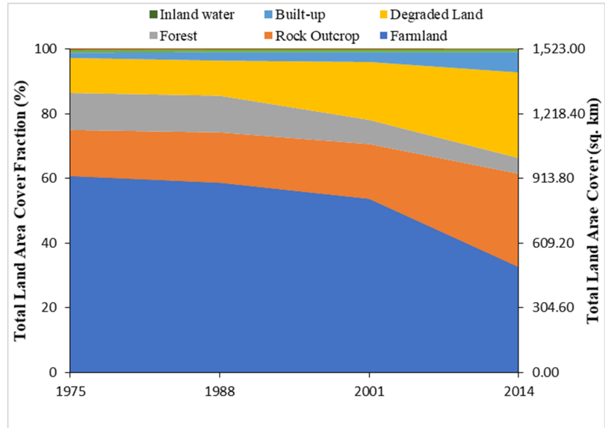


Figure 4. Temporal changes in the distribution of different land cover classes in the studied area.

Table 3. Classification accuracy assessment for year 1975.

LULC type	FOR	WB	DL	FL	BU	RO	Producer's accuracy (%)	User's accuracy (%)
FOR	97.60	0.00	1.00	0.60	0.00	0.80	97.6	95.6
WB	0.00	99.48	0.52	0.00	0.00	0.00	99.48	95.64
DL	2.40	0.00	97.60	0.00	0.00	0.00	97.6	92.96
FL	0.00	0.00	0.60	99.40	0.00	0.00	99.4	90.49
BU	0.00	0.52	0.28	0.00	98.60	0.60	98.6	98.6
RO	0.00	0.00	0.00	0.00	1.40	98.60	98.6	96.2
Overall classification accuracy = 98.55%								

Table 4. Classification accuracy assessment for Year 1988.

LULC type	WB	FOR	DL	BU	RO	FL	Producer's accuracy (%)	User's accuracy (%)
WB	97.20	0.00	0.00	0.00	2.8	0.00	97.2	98.68
FOR	0.00	95.59	0.00	0.00	4.41	0.00	95.95	96.2
DL	0.00	0.00	95.6	2.50	1.82	0.00	95.6	94.7
BU	0.00	0.00	0.62	97.50	1.88	0.00	97.5	90.1
RO	2.80	4.41	3.70	0.00	83.57	5.52	83.57	98.6
FL	0.00	0.00	0.00	0.00	5.52	94.48	94.48	88.6
Overall classification accuracy = 94.05%								

Table 5. Classification accuracy assessment for year 2001.

LULC type	FOR	WB	FL	DL	RO	BU	Producer's accuracy (%)	User's accuracy (%)
FOR	97.25	0.00	0.56	0.00	2.19	0.00	97.25	90.48
WB	0.00	96.84	0.00	0.00	3.16	0.00	96.84	91.7
FL	1.83	0.00	92.74	0.58	4.85	0.00	92.74	91.4
DL	0.00	0.00	0.00	88.95	0.00	11.05	88.95	91.4
RO	0.92	3.16	6.70	2.91	85.43	0.88	85.43	96.8
BU	0.00	0.00	0.00	7.56	4.37	88.07	88.07	95.6
Overall classification accuracy = 91.55%								

Table 6. Classification accuracy assessment for year 2014.

LULC type	WB	FOR	RO	BU	FL	DL	Producer's accuracy (%)	User's accuracy (%)
WB	100.00	0.00	0.00	0.00	0.00	0.00	100	91.28
FOR	0.00	95.85	0.65	0.00	3.50	0.00	95.85	95.6
RO	0.00	3.81	96.19	0.00	0.00	0.00	96.19	91.4
BU	0.00	0.34	3.07	93.11	0.00	3.48	93.11	91.6
FL	0.00	0.00	0.09	0.35	96.5	3.06	96.5	97.6
DL	0.00	0.00	0.00	6.54	0.00	93.46	93.46	95.6
Overall classification accuracy = 95.85%								

3.2.1. Mining Degraded Area

The degraded land increased from 165.1 km^2 (10.8%) in 1975 to 165.5 km^2 (10.9%), 272.9 km^2 (17.9%), and 403.3 km^2 (26.5%) in 1988, 2001, and 2014, respectively (Figure 4). The degraded land is as a result of the continuous mining activities in the areas.

The mining activities is known to render land bare leading to massive gullies, excessive run-off, heavy erosion, reduced soil infiltration, reduction in groundwater recharge, and the consequent loss of land productivity, as experienced in the studied area [5]. This may culminate in the destruction of the luxuriant vegetation, bio-diversity, cultural sites, and water bodies.

Erosion could result in the removal of soil nutrients, causing siltation; thus leading to reduction of land productivity and reduced bio-diversity, among others. This area is liable to erosion as a result of the lack of the existing vegetation, the presence of finely dispersed small particles, and steep slopes, forming huge gullies and pits. The productive arable lands could be made barren.

The exploitation of mineral resources often leads to extensive soil degradation through the destruction of vegetation and alteration of microbial communities, resulting in low soil nutrients, fertility, and productivity. Soil degradation was caused by erosion, resulting in the loss of soil nutrients, organic matter, and damage to the properties of soil and crops.

Mounds of mine wastes in the studied area may reduce the quality of the soil resources, as stockpiling are known to reduce the soil aerobic and anaerobic organisms. Plant propagules may die, and populations of useful soil microorganisms are reduced significantly. The process of stockpiling also generates heat that kills some soil-beneficial organisms that cannot survive such high temperatures. Most mining sites in the studied area exhibit low pH and low levels of soil macronutrients such as nitrogen and phosphorus that are necessary for crop production [5].

3.2.2. Water Body

The area covered by water bodies increased from 13.6 km^2 (0.89%) in 1975 to 13.7 km^2 (0.90%), 14.0 km^2 (0.92%), and 14.5 km^2 (0.95%) in 1988, 2001, and 2014, respectively (Figure 4). The area covered by water increased with increase in the total area of land degraded by the mining activities in the studied area from 1975 to 2014.

Mining ponds occuring due to abandoned open-pit mines could enhance erosion. Such ponds often contain waste that make them unable to support any form of life. There could be leaching of excess quantities of major and trace elements when compared to the World Health Organization (WHO) drinking water standards; thereby, making the water unwholesome. There are cases of accidents in the studied area as these ponds that are not fenced have a close proximity to the populated areas. The most devastating effect of this is the surface and groundwater pollution. The current search for gemstones in the studied area has further increased the devastation of the environment since pits and trenches are dug in search for the pegmatite containing gemstones.

3.2.3. Built-up/Developed Area

The developed area increased from 24.6 km^2 (1.62%) in 1975 to 39.5 km^2 (2.59%), 45.8 km^2 (3.0%), and 96 km^2 (6.3%) in 1988, 2001, and 2014, respectively (Figure 4). This increase in the developed area indicates that mining has brought development to the studied area. This increase may either imply that the mining activities did not only lead to the socio-economic improvement of the practitioners but also led to migration into the studied area and development of the studied area or simply followed from increase in population in the surrounding communities.

3.2.4. Cultivated Land

The cultivated farmlands decreased from 924.6 km^2 (60.87%) in 1975 to 893.7 km^2 (58.68%), 817.8 km^2 (53.7%), and 496.2 km^2 (32.6%) in 1988, 2001, and 2014, respectively (Figure 4). This decrease in the area covered by cultivated farmland is as a result of loss of arable farmland and soil nutrients owing to the mining activities in the studied area.

The impact of mining in the studied area revealed that mining removed vegetation and topsoil, and often resulted in an inevitable loss of farmland permanently. Important soil organisms could have been destroyed and stable soil aggregates disrupted, and eventually, depriving the soil of organic matter and low levels of macronutrients and soil fertility necessary for plant growth and crop production. These soils or newly created substrates/growth are often inhospitable to vegetation due to a combination of the physical, chemical, and microbiological factors [54]. This inevitably leads to pending food insecurity in the long run.

3.2.5. Forest

The forested region of the studied area decreased from 174.8 km^2 (11.5%) in 1975 to 173.1 km^2 (11.4%), 114 km^2 (7.5%), and 74.2 km^2 (4.9%) in 1988, 2001, and 2014, respectively (Figure 4). The expansion of mining pits required clearing of the vegetation around them resulting in deforestation.

The natural ecology was greatly impacted by deforestation, and the mine sites became prone to erosion due to the lack of vegetation in the areas. The results obtained showed that surface mining resulted in deforestation, a substantial loss of farmland, and widespread spill-over effects as relocated farmers expanded farmlands into forests. This point to rapidly erode livelihood foundations suggest that the environmental and social costs of tin mining in the studied area may be much higher than previously thought. Mining had resulted in extensive land cover changes, leading to the loss of forests and farmlands. Mining in the studied area appears to displace farmers, thereby, triggering increased deforestation, agricultural intensification, and land degradation. Thus it may have additional, substantial indirect social, and environmental cost in addition to the direct costs of mining that are widely known. The farmland displacement due to mining in the studied area may exert additional pressure on the remaining forests outside concessions. Mining may be the principal driver of forest and farmland loss in the studied area.

3.2.6. Rock outcrop

The area covered by the exposed rock surface increased from 217.9 km^2 (14.3%) in 1975 to 237.5 km^2 (15.6%), 258.5 km^2 (17%), and 691.3 km^2 (45.4%) in 1988, 2001, and 2014, respectively (Figure 4). This increase is as a result of the mining activities and the resultant deforestation in the studied area.

4. Recommendation for restoration and sustainable mining operation

In the developing countries (like Nigeria), the mining operations, most especially small-scale miming had caused serious damages to the environment due to the reduction of forest cover, land degradation, air and water pollution, and ultimately, reduction in bio-diversity. Surface mining, for example, removes vegetation and soils, interrupts ecosystem service flows, and results in an inevitable and often permanent farmland loss. The presence of scores of mine pits in the areas where mining activities were concentrated, which were often filled with water, could host pathogens (disease causing agents) as well as pose hazards to the human and animal lives. As such, there is, therefore, a need for a proper restoration of the minefields to reduce the existing hazards and prevent further environmental degradation.

Mining operations, though an indispensable economic activity, require an effective management (monitoring, control, and restoration) to curb the undesirable environmental degradation. In order to minimize the damage caused by mining operations, there is a need for a well laid down rules and regulations to guide the mining operations. The mining companies and small-scale miners must be aware of the potential impacts of their activities, and the laws enforcing them to plan and execute strategies to have positive net outcomes that are sustainable in the long run must be enacted. To effect these laws and combat indiscriminate mining activities, measures should be taken to encourage accountability and transparency among the government officials who are saddled with these responsibilities. Due to the remoteness of mining locations, the government officials are liable to bend established laws through the collection of funds outside their functions as the government representatives. Such activities are counter-productive and destroy the creed of sustainable development. However, if the government could enforce accountability for all payments among its representatives, these activities can be curtailed.

Furthermore, in the areas already degraded, reclamation of the devastated land that is an important component of restoration could facilitate the socio-economic development of the area. The ponded pits should, therefore, be reclaimed after they are dewatered. This will create useful landscape and productive ecosystems from the devastated mine land. The back-filling method of reclamation is mostly suggested except in pits that are excavated in benches (layers), where the terracing reclamation method will be suitable.

However, not all the pits can be reclaimed due to the volume of the earth materials that would be required. Some ponds can, therefore, be put to economic use such as the recreation activities, agriculture (irrigation and aquaculture), and water supply for domestic and industrial purposes after the water had been treated and the quality ascertained.

Revegetation is also suggested to preserve the recovered arable farmlands, while afforestation is recommended to increase the forest in the area. A proper afforestation scheme with adequate plan will not only preserve the forest but also the wildlife therein.

5. Conclusinns

A geo-environmental evaluation of the mine sites in the Jos area was carried out. The digital terrain map produced in this work revealed that the mining activities were concentrated around the central part of the studied area, resulting in their low elevations. The edges of the studied area had high land-terrains with steepness down their respective centres. The results obtained show that out of the 1,523 km^2 total size of the studied area, the degraded area/land, built-up area, water bodies, and exposed rock outcrop increased by 238.2 km^2 (15.68%), 71.4 km^2 (4.68%), 0.9 km^2 (0.06%), and 220.9 km^2 (14.5%), respectively, and the arable farmland and forest reserve decreased by 430.8 km^2 (28.29%) and 100.6 km^2 (6.63%), respectively. The source of livelihood of the local residents is mostly farming. Thus it was established that mining of tin and the associated minerals in the studied area had resulted in a high degree of degradation of arable land, forest, and landscape as well as other environmental problems.

Mining has greatly affected the natural ecology, and therefore, the mine sites should be monitored, and their environmental damages should be determined and mitigated. There should be regular inspections to keep these activities under control.

It is also recommended that there should be an effective community participation in the environmental decision-making to ensure sustainable mining activities; easing of the registration process for small-scale mines; addressing the various weaknesses in the policies and their enforcement in the mining sector; establishment of environmental oversight groups in the mining communities; and creating environmental awareness campaigns and/or education in the mining communities.

Refrences

[1]. Akabzaa, T. and Darimani, A., 2001. Environmental impacts of mining: A study of mining communities in Ghana. Applied Ecology and Environmental Sciences, 3(3), 81-94.

[2]. Indo-Asian News Service, (2006). Measures to stop illegal mining. (Ranchi, India: Indo-Asian News Service).

[3]. Andoh, A.C., 2010. Mining and the environment in Ghana. Presented at the 1st UMAT International Mining and Mineral Conference, 4-7 August.

[4]. Asiam, E.K., 2010. Ethics in mining: Advocacy for solving environmental issues in mining. Presented at the 1st UMAT International Mining and Mineral Conference, 4-7 August.

[5]. Omotehinshe A O and Ako B D., 2019. Journal of Sustainable Mining, 18, 18-24.

[6]. Adiukwu-Brown, M.E. (1999). The dangers posed by abandoned mine ponds and lotto mines on the Jos-Plateau. Journal of Environmental Sciences, 3(2), 258-265.

[7]. Mallo S.J., 2007. Minerals and mining on Jos-Plateau (Jos: Yinka Elushade Ventures Limited) pp. 146,147.

[8]. Olaniyan J.A., 1998. Overview of the socio-economic impact of tin mining. (Jos: State Secretariat Cabinet Office).

[9]. Aguigwo, E.N., 1997. The characteristics and viability of informal mining on the Jos-Plateau, Doctoral Thesis, University of Jos.

[10]. Aigbedion, I. and Iyayi, S.E., 2007. “Environmental effects of mineral exploitation in Nigeria”. International Journal of Physical Sciences 2(2), 33-38.

[11]. Ndace, J.S. and Danladi, M.H., 2012. Impacts of derived tin mining activities on landuse/landcover in Bukuru, Plateau State, Nigeria. Journal of Sustainable Development, 5(5), 90-99.

[12]. Isirimah, N.O., 2003. Land degradation and Rehabilitation. Presented at the 29th Annual Conference of Soil Science Society of Nigeria, 1-4 August.

[13]. Osuji, L.C and Nwoye, I., 2007. An appraisal of the impact of petroleum hydrocarbons on soil fertility: The Owaza experience. African Journal of Agricultural Research, 2(7), 318-324

[14]. Yazdi, Z., Jafari Rad, A., Aghazadeh, M., Afzal, P., 2018. Alteration Mapping for Porphyry Copper Exploration Using ASTER and QuickBird Multispectral Images, Sonajeel Prospect, NW Iran. Journal of the Indian Society of Remote Sensing 46 (10): 1581–1593.

[15]. Shahsavar, S., Jafari Rad, A., Afzal, P., Nezafati, N., Akhavan Aghdam, M., 2019. Prospecting for polymetallic mineralization using stepwise weight assessment ratio analysis (SWARA) and fractal modeling in Aghkand Area, NW Iran. Arabian Journal of Geosciences 12 (7), 248-257.

[16]. Fox, J., R.R. Rindfuss, et al., 2002. People and the environment: Approaches for linking household and community surveys to remote sensing and GIS. Dordrecht: Kluwer.

[17]. Liu, J.G., T. Dietz, et al., 2007. Coupled human and natural systems. AMBIO 36: 639–649.

[18]. Turner, B.L., E.F. Lambin, et al., 2007. The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences of the United States of America 104(52): 20666–20671.

[19]. Meyer, W., 1995. Past and present land-use and land-cover in the U.S.A: Consequences. Presented at the 2nd Annual conference of remote sensing, Colorado, USA, 1-4 April

[20]. Lambin E. F., Turner, B. L., Geist, Helmut J., Agbola, Samuel B., Angelsen, Arild, Bruce, John W. et al., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11(4), 261-169.

[21]. Daniel, D., 2002. A comparison of land use and landcover change detection methods Presented at the 1st Annual conference of remote sensing, Lagos, Nigeria, 4-6 August.

[22]. Igbokwe, J.I., 2010. Modelling of landcover and land use patterns of Onitsha and environs using NigeriaSat-1 image data. Presented at the 40th Annual General Meeting and conference of the Nigerian Institution of Surveyors, Kano, Nigeria, 7-8 February.

[23]. Braimoh. A. K. 2006. Random and Systematic Land-Cover Transitions in Northern Ghana, Agriculture, Ecosystem and Environment, 113, 254-263.

[24]. Nagendra, H., Munroe, D.K., Southworth, J., 2004. From pattern to process: Landscape fragmentation and the analysis of land use/land cover change Agriculture. Ecosystem Environment. 101 (2/3), 111–115.

[25]. Onwuka, S.U., Duluora, J.O. and Okoye C.O., 2013. Socio-economic impacts of tin mining in Jos, Plateau State, Nigeria. International Journal of Engineering Science Invention, 2(7), 30-34.

[26]. Balogun, T., 2007 The changing landscape of Jos, Nigeria. Available online at: http://www.escapeartist.com/efam/97/changing-landscape-of-jos.html (accessed: 20th September, 2017).

[27].Adegboye M.A., 2012. Effect of mining on farming in Jos South Local Government Area of Plateau State. Journal of Soil Science and Environmental Management, 3(4), 77-83

[28]. Dukiya, J., 2013. The environmental implication of illegal mining activities in Nigeria: A Case Study of Pandogari and Barkin Ladi/Bukuru surface mines in Niger/Plateau States. Journal of Humanities and Social Sciences, 13(5), 13-19.

[29]. Lar, U.A., 2007. Geology and mineral resources of Plateau State. (Nigeria: University of Jos Press), pp 28-30.

[30]. Owolabi, A.O., 2017. Geoenvironmental evaluation of abandoned mine sites in Jos Area, Plateau State, Nigeria. Doctoral Thesis, The Federal University of Technology Akure

[31]. Obaje, H.G. 2009. Geology and Mineral Resources of Nigeria. Lecture Notes in Earth Sciences, Springer-Verlag Berlin Heidelberg. 120: 31-48.

[32]. Owolabi, A. O., 2018. Assessment of radioactive contamination in water bodies around mine workings using radiation counter. Journal of Mining & Environment, 9(4): 795-806.

[33]. Opafunso, Z.O. and Owolabi, A.O. (2016). Measurement of Radioactivity in Mine Waste, Soil and Water of Selected Mine sites in Plateau States, Nigeria. Proceedings of the fourth Biennial UMaT International Conference on Mining & Mineral Processing, Tarkwa, Ghana, 1st-4th, August PP. 123-133.

[34]. Owolabi, A.O., Opafunso, Z.O. and Lajide, L. (2017). Radiogenic Characterisation of Wastes and Soil Samples around Cassiterite Mine Sites. International Journal of Engineering and Technology. 7 (3): 495-499.

[35]. Kamp U, Bolch T, Olsenholler J., 2005, Geomorphometry of Cerro Sillajhuay (Andes, Chile/Bolivia): comparison of digital elevation models (DEMs) from ASTER remote sensing data and contour maps. Geocarto Int 20(1):23–33.

[36]. Ozdemir H, Bird D., 2009, Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. Environ Geol 56:1405–1415.

[37]. Patel, P. P and Sarkar, A., 2010, Terrain Characterization using SRTM Data. J. Indian Soc. Remote Sens. 38:11–24.

[38]. Farr, T. G., Rosen, P.A., Caro, E., Crippen, R., Duren, R Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D.,Alsdorf, D., 2007. The shuttle radar topography mission. Review of Geophysics, 45 (2), 24, 25.

[39]. Hegazy, I. R., Kaloop, M. R., (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. International Journal of Sustainable Built Environment. 4, 117−124.

[40]. Mertens, B., Lambin, E.F., 2000. Land-cover change trajectories in Southern Cameroon. Ann. Assoc. Am. Geogr. 90 (3), 467–494.

[41]. Campbell, J.B., 2002, Introduction to remote sensing, Taylor & Francis, London.

[42]. Iqbal, M. F., & Khan, I. F. (2014). Spatiotemporal land use land cover change analysis and erosion risk mapping of Azad Jammu and Kashmir, Pakistan. The Egyptian Journal of Remote Sensing and Space Sciences, 17, 209–229.

[43]. Awoniran, D.A., 2014. Assessment of environmental responses to landuse/land cover dynamics in the lower Ogun river basin, Southwestern Nigeria. African Journal of Environmental Science and Technology 10(5), 152-165.

[44]. Owojori, A., & Xie, H. (2005). Landsat image-based LULC changes of San Antonio, Texas using advanced atmospheric correction and object-oriented image analysis approaches. Paper Presented at the 5th international symposium on remote sensing of Urban Areas, Tempe, AZ.

[45]. Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., 2004 Remote Sensing and

Image Interpretation, John Wiley & Sons, Hoboken, NJ, USA.

[46]. Ishola, K. A., Okogbue, E. C., & Adeyeri, O. E. (2016). Dynamics of surface urban biophysical compositions and its impact on land surface thermal field. Modeling Earth System and Environment, 2, 208.

[47]. Adepoju, M.O. Millington, A.C. Tansey, K.T., 2006. Land use/land cover change detection in Lagos Metropolis, Nigeria, Presented at the 12th Annual conference Reno, Nevada. 7-8 April.

[48]. Zubair, A.O., 2006. Change detection in landuse and landcover using remote sensing data and GIS. A case study of Ilorin and its environs, MSc Thesis, University of Ilorin.

[49]. Ritter DF, Kochel RC, Miller JR ,2002, Process geomorphology. McGraw Hill, Boston.

[50]. Singh O, Sarangi A, Sharma MC (2008) Hypsometric integral estimation methods and its relevance on erosion status of northwestern Lesser Himalayan watersheds.Water Res Manag 22:1545–1560.

[51]. Prasannakumar, V., Vijith, H and Geetha, N., 2013, Terrain evaluation through the assessment of geomorphometric parameters using DEM and GIS: case study of two major sub-watersheds in Attapady, South India Arab J Geosci (2013) 6:1141–1151.

[52]. Scepan, J., (1999). Thematic validation of high-resolution global land-cover data sets, Photogrammetric Engineering and Remote Sensing, 65, 051–1060.

[53]. Lea, C., and Curtis, A. C. (2010). Thematic accuracy assessment procedures: National Park Service Vegetation Inventory, version 2.0. Natural Resource Report NPS/2010/NRR 2010/204, National Park Service, Fort Collins, Colorado, USA.

[54]. Mensah A. K., 2015. Role of revegetation in restoring fertility of degraded mined soils in Ghana: A review. International Journal of Biodiversity and Conservation 7(2): 57–80.

ارزیابی تغییرات سطح زمین، کاربری زمین و پوشش زمین در زمین‌های معدنی با استفاده از تکنیک‌های مکانی در ایالت پلاتو، نیجریه

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چکیده:

در این مقاله، یک ارزیابی مکانی از سایت‌های منتخب معدنی در ایالت پلاتو، نیجریه گزارش شده است. هدف از این کار تعیین تأثیر استخراج معادن بر زمین و همچنین استفاده از زمین و پوشش زمین (LULC) در جوامع میزبان است. برای نقشه برداری زمین از رادار شاتل (SRTM) استفاده شده است. عوامل موثر بر تاثیر استخراج معادن در LULC بین سال‌های ۱۹۷۵ و ۲۰۱۴ با طبقه بندی تصاویر مربوط به Landsat تعیین می‌شود. نقشه دیجیتال زمین نشان دهنده آن است که فعالیت استخراج به خوبی با محیط پیرامون هماهنگ نیست. قسمت‌هایی از سایت‌های معدن که غنی از مواد معدنی مورد نظر هستند با عمق کم استخراج می‌شوند، در حالی که قسمت‌های دیگر در نتیجه فعالیت معدنکاری تصادفی دارای زمینی با ارتفاع بیشتر هستند. تجزیه و تحلیل تغییر LULC نشان می‌دهد که زمین تخریب شده (DL) ، منطقه ساخته شده (BU) ، پساب‌ها (WB) و رخنمون سنگ(RO) به ترتیب٪۱۵/۶۸، ٪۴/۶۸، ٪۰/۰۶و ٪۱۴/۵ افزایش یافته است، در حالی که میزان زمین‌های زراعی قابل کشت (FL) و ذخیره جنگل (FR) به ترتیب ٪۲۹/۲۸ و ٪۶/۶۳ کاهش یافته است. معدنکاری بر محیط زیست طبیعی منطقه مورد مطالعه تأثیر منفی گذاشته است. بنابراین، سایت‌های معدن باید تحت نظر قرار گیرند و آسیب‌های زیست محیطی آنها باید از قبل تعیین شده و کاهش یابد. برای کنترل این فعالیت‌ها باید مرتباً بازرسی صورت گیرد. قوانین و مقررات موجود برای حفاظت از اکوسیستم‌های طبیعی جوامع میزبان باید برای محدود کردن مازاد بهره برداران صنایع معدنی اجرا شود. بازسازی زمین‌های معدنی برای کاهش خطرات موجود از تخریب بیشتر محیط زیست جلوگیری می‌کند و همچنین تسهیل توسعه اجتماعی - اقتصادی منطقه نیز پیشنهاد می‌شود.

کلمات کلیدی: جغرافیا، زمین، SRTM، LULC، طبقه‌بندی.