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# ANALYSIS OF THE EFFECTS OF ARTISANAL MINING ON THE VEGETATION COVER IN KADUNA STATE, NIGERIA

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**ABSTRACT**

This study was carried out in BirninGwari L.G.A of Kaduna State, Nigeria, to assess the effects of artisanal mining on vegetation cover. Landsat images were used to establish the extent and trend of vegetation cover affected by gold mining. The downloaded images were processed, geo-referenced and classified with G.I.S Software. It was discovered that from 1999 to 2015, the vegetation cover in the study area declined from 1082 $km^2$ to 601.8 $km^2$ as well as a corresponding decrease of 0.2043 in Normalized Difference Vegetation Index (NDVI)value from 0.3543 within the years 1999-2007 and to 0.1500 within the years spanning 2007-2015 signifying a decrease in vegetation cover. This decrease in vegetation cover and NDVI value can be attributed to the on-going mining operation. Furthermore, on forecasting future effects using the Least Square Forecasting tool within the next 16 years, the extent of vegetated land is expected to dip by 18.7% to 112.73 $km^2$ if this method of mining is not checked in the study area.

**Key words:** Artisanal Mining, Forecasting, Image processing and Vegetation Cover.

## INTRODUCTION

Mining of solid minerals pervade the entire Nigeria leaving behind vivid effects on the environment especially vegetation cover [1-5].

The history of mining was one of small-scale operations, often crude, in terms of technology but still providing the necessary raw materials for the industries and society.

Presently, mining operations have greatly improved with large quantities of resources being mined by large companies but this has not translated into improved living standards of indigenes thus; necessitating the re-emergence of small-scale mining [6].

Artisanal and small-scale mining refers to any mining operation practiced by individuals, groups or communities with crude equipment often illegally and in developing nations.

Directly or indirectly, mining is a major factor responsible for vegetation loss in mining areas all over the world [6, 7]. Directly, it involves vegetation clearance for various mining activities. While indirectly, there is discharge of a lot of toxic dust which eventually settle on the plant leaves and flowers thereby affecting the biophysical aspect of the vegetation. According to the British Broadcasting Corporation [8], the United Nations had warned on environmental crises especially on the adverse effects of destruction of tropical rain forests. In the report, the United Nation Environmental Programme [9], Global Environment Outlook [10] stated that the continued poverty of the majority of the planet inhabitants and excessive consumption of natural resources by the minority are the two major causes of environmental degradation.

Atiqur *et al*. [11] used Remote Sensing Data and GIS techniques to assess the Land-Use/Land-Cover change in north-west district of Delhi from 1972 to 2003 and observed that 92.06% of the land which was under agricultural practice in 1972, reduced to 64.71% in 2003 indicating a 27.35% decrease in agricultural land. While built up area, which was 6.31% in 1972, increased to 34% in 2003. Furthermore, Mkaanem [12] from her research discovered that from 1976 to 2001, vegetated land in the Mbayion area of Benue State Nigeria has reduced from 42.22% to 28.90% as a result of mining. Also, Musa and Jiya [13] assessed the impact of mining activities on the vegetation cover of Bukuru, Jos, Nigeria, from 1997 to 2007 and discovered a NDVI decline of vegetated land from 0.063 in 1986 to 0.050 in 2007. Merem *et al*. [14] used descriptive statistics and GIS methodology in analyzing the ecological impact of mining in Nigeria where they concluded that declines in forest land in Bukuru, Plateau state, Nigeria, fell from 420.52 $km^2$ in 1975 to 399.56 $km^2$ over time in 1986.

The aim of the study is to assess the effects of artisanal mining activities on vegetation cover in BirninGwari Local Government Area of Kaduna State. This aim will be achieved through the following objectives which are to:

i. locate and map out the mining sites in BirninGwari Local Government Area of Kaduna State.

ii. determine the spatial extent and trend of mining in the study area from 1999 to 2015.

iii. examine the effects of gold mining on the vegetation cover of the study area from 1999 to 2015 using NDVI.

iv. forecast effects of artisanal gold mining on the vegetation cover in the study area using statistical tool.

**Study Area**

BirninGwari (Figure 1), a Local Government Area in Kaduna State, North-Western Nigeriais not spared from the menace of artisanal mining as can be seen in its vegetation cover which has been greatly altered from its natural state to a modified state. This area is situated on the southern end of the high plains of Northern Nigeria, bounded by parallels $10^0 58'$N and $11^0 11'$ N and has an area of 6,185 km² along Kaduna- Lagos express way at about 125km from Kaduna [15, 16]. Due to its association with schist belt of the Nigerian basement complex, Woakes and Bafor [17] have designated it as an area graced with gold mineralization.

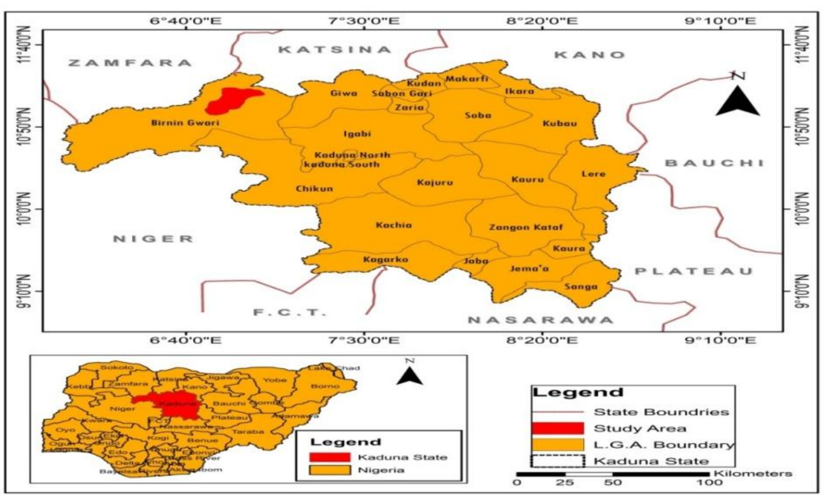


Figure 1: Geographical Location of the Study Area [18]

## EXPERIMENTAL

Materials used were majorly hand held Global Position System and Geographic Information System Software (Erdas imagine 9.2 and Arc GIS 10.1). The study adopted the use of Remotely sensed satellite imagery, Geographic information system and statistical analysis. Data used for the study included: Coordinates of representative sample sites of known Land-Cover types during image classification, Landsat Enhanced Thematic Mapper Plus Images of October 1999 and November 2007 with Spatial Resolution of 30m, Landsat 8 Images of March 2015 with Spatial Resolution of 22 m. Based on the sampling frame, purposive sampling technique was adopted since it is useful for identifying specific cases for detailed investigation.

The TM/ETM data were used in the detection of Land-Use change. Geometric disturbances were systematically corrected through image preprocessing (geometric rectification, registration, and clipping). Colour composites and band rationing were used as the major enhancement technique in this work. Digital image-processing software Erdas imagine 9.2was used to rectify and re-sample, while Arc GIS 10.1 processed, analyzed and integrated spatial data.

After re-sampling, the images were used to generate Land-Use/Land-Cover maps of the study area. In the process, Erdas Imagine 9.2 software was used to generate a false colour composite of each image, by combining near infrared, red and green bands (band 4, 3, 2) for those images in order to enhance vegetation recognition. The false colour composite images were then imported into Arc GIS 10.1 for further processing and classification.

The satellite images (ETM+ with spatial resolution of 30m and Landsat 8 spatial resolution of 22 m) were all imported into Erdas Imagine 9.2 environment where they were rectified to a common projection (Universal Traverse Mercator). The process involved assigning geographic information like location and position to the datasets and aided in defining the existence of those data sets in physical space and also their location in the real world.

In classifying the images, supervised classification technique was done using maximum likelihood algorithm which enabled the analyst to generate training classes based on the actual Land-Use/Land-Cover themes present within the study area. Sample sites were selected based on spectral signatures of features in the images. Known Land-Cover types (training sites) were also coded with names of the corresponding thematic feature. After this, maximum likelihood classification technique was employed in classifying the images into Bare land, Vegetated land

and Mining sites. The classification in Table 1 is a modification of Anderson *et al*, [19].

Table 1: Land Use/Land Cover Classification Scheme

| CODE | LAND COVER/LAND USE CATECORIES | DESCRIPTION |
|---|---|---|
| 1 | Bare land | Land devoid of vegetation; composed mainly of sand and rock |
| 2 | Vegetated land | Land covered with natural forest and natural vegetation |
| 3 | Mining site | Exposed soils and land devoid of vegetal cover |

***Accuracy Assessment***

In order to test the accuracy of the classification, Eight (8) points for each Land-Use/Land-Cover class were randomly collected from the field using a GPS and was inputted into ArcGIS environment where the Kappa coefficient was used to test the accuracy of the classification. A Kappa coefficient value of 0.64 was obtained and this signifies that the classification accuracy was moderate [20].

**FORECASTING**

Forecasting is the prediction for the future, which by its nature is unknown [21]. It is applicable when a said activity or action (*in this case artisanal mining*) on an object (*vegetation cover*) does not change its course of action and when the said object is observed to be undergoing noticeable changes. Long term forecasting method was adopted where the trend was projected by a statistical method known as method of *least of squares, d*enoted by the following formulas.

$$\Sigma Y = n.a + b\Sigma X \ldots\ldots\ldots\ldots(1)$$

$$\Sigma XY = a\Sigma X + b\Sigma X^{2} \ldots\ldots\ldots(2)$$

Where **"Y"** = Sq.km Area of vegetation within the year; **"X"** = Number of years under review; **a" and "b"** are Constant

This study covered a sixteen (16) years period of artisanal mining spanning 1999 to 2015. Vegetation cover in the study area is been cleared by the aggressive gold miners who have one goal: to dig out gold no matter what happens to the land in the process. The area is characterized by Northern Guinea Savannah which consists mainly of herbs and shrubs with some deciduous trees scattered.

## RESULTS AND DISCUSSION

Hand held Global Position System was taken to the various mining sites where their coordinates were obtained (Table 2). These coordinates were overlaid on the base map of the study area. Figure 1 represents the locations of the mining sites in the study area.

Table 2: Description of sites (mining and agricultural activities) in the study area.

| MINING SITE | LOCATION |
|---|---|
| 1) Jan-Ruwa village | N10°59'41.4'', E006°48'25.8''<br>Elevation: 555m, Accuracy: 8 m |
| 2) Company in Jan- Ruwa area | N10°59'21.4'', E006°48'31.5''<br>Elevation: 561 m, Accuracy: 8 m |
| 3) Abuja Artisanal mining camp | N10°59'14.7'', E006°48'38.5''<br>Elevation: 564 m, Accuracy: 8 m |
| 4) Junction into Jan-Ruwa village | N10° 58'46.0'', E006°47'35.0''<br>Elevation: 658 mAccuracy: 7m |
| 5) Farming area | N11°11'56.6'', E006°56'09.3''<br>Elevation: 658 m, Accuracy: 7 m |
| 6) Marabakakini gold mine at Kuyello town in BirninGwari L.G.A | N11°11' 11.8'', E006°58'43.4''<br>Elevation: 682 m, Accuracy:8 m |
| 7) YakanDutshe (Hill) | N11°10'37.9'', E006°59'11.4''<br>Elevation: 692 m, Accuracy: 8 m |
| 8) Localgold mine in Kakinni area. | N11°10'28.5'', E006°59'03.8''<br>Elevation 692 m, Accuracy: 8m |

Data were obtained in the field

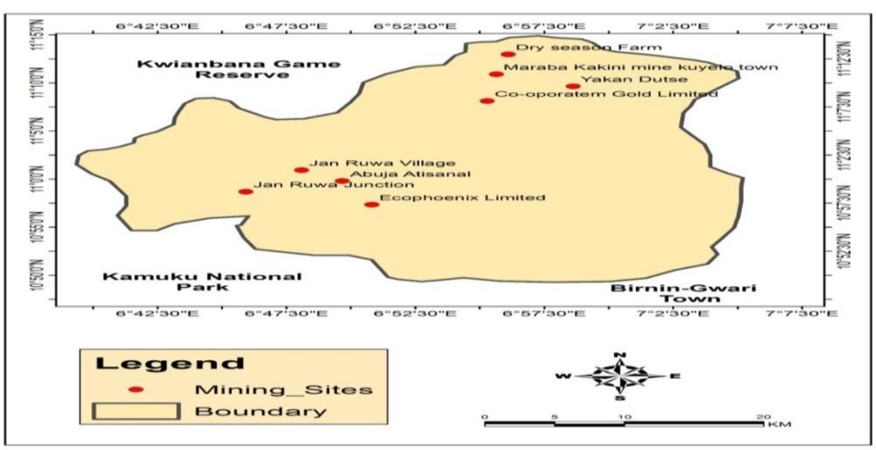


Figure 2: Location of Mining Sites in BirninGwari L.G.A [22].

Eight (8) sites were identified in the study area (Figure 2). Mining sites here are nucleated with a separating distance of about 18km between each cluster. Concentrations of mining sites in the north-east and south-west of the map suggest possible enrichment of mineral horizons as well as great ease of mineral exploration in these areas.

**Extent and Trend of Mining Sites in BirninGwari**:

The spatial extent and trend of the mining site over the period of study was determined by image supervised classification in Erdas Imagine version 9.2. Figures 3 to 5 present the extent of the mining sites over the period of study while Table 3 shows the area coverage in $km^2$, percentage of area occupied by mining sites as well as the other Land-Cover types in the study area

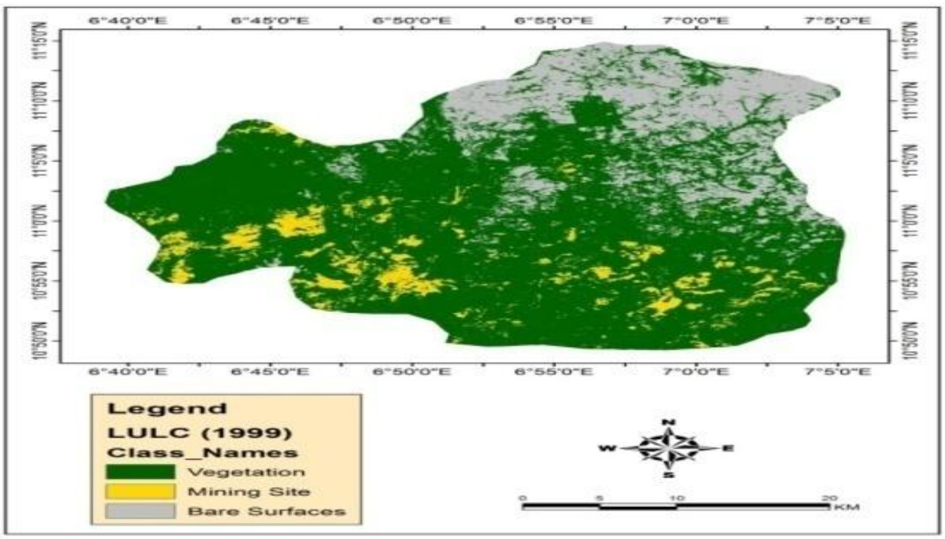


Figure 3: Extent and Trend of Mining Sites in BirninGwari L.G.A. in 1999

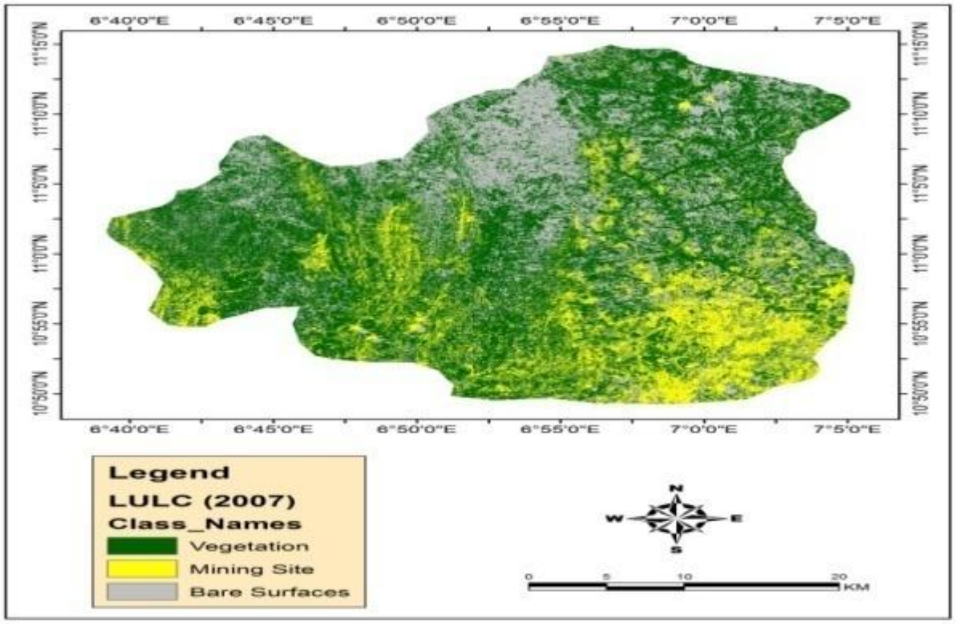


Figure 4: Extent and Trend of Mining Sites in BirninGwari L.G.A. in 2007

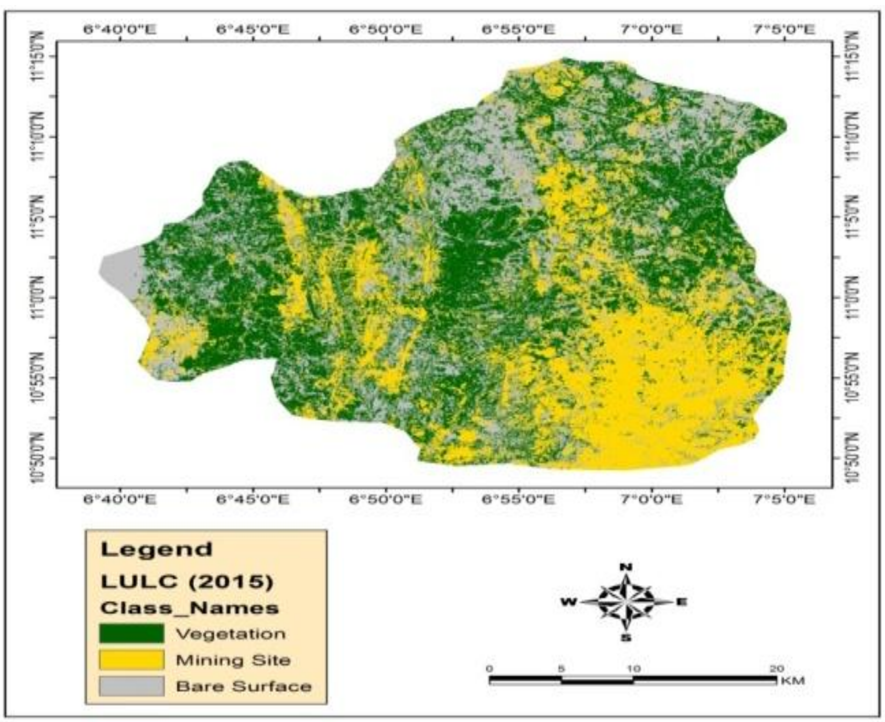


Figure 5: Extent and Trend of Mining Sites in BirninGwari L.G.A. in 2015

Table 3: Spatial Extent of the Mining Site between 1999 and 2015.

| | Area in Sq. Km | | | | | |
|---|---|---|---|---|---|---|
| **LULC** | **1999** | **%** | **2007** | **%** | **2015** | **%** |
| Mining Site | 103.0 | 6.9 | 278.7 | 18.6 | 466.5 | 31.1 |
| Bare Surfaces | 317.1 | 21.1 | 408.0 | 27.2 | 433.8 | 28.9 |
| Vegetation | 1082.0 | 72.0 | 815.3 | 54.3 | 601.8 | 40.1 |
| **Total** | **1502.1** | **100.0** | **1502.1** | **100.0** | **1502.1** | **100.0** |

The results in Table 3 showed that the study area covered 1502.1 square kilometer of which vegetation cover dominated with 1082.0 sq. km (72.0%), its highest value during the period under review. The bare surface on the other hand covered 317.1 $km^2$ (21.1%), its least value during this time frame and the mining site covered an area of 103.0 $km^2$ (6.9%) in 1999 with a promising future. In 2007, however, the mining site appeared to have more than doubled to 278.7 $km^2$ (18.6%), the bare surfaces also increased to 408.0 $km^2$ (27.2%) while the vegetation cover reduced to 815.3 $km^2$ (54.3%). This can readily be traced to increased mining operation (Land-Use) within the study area as previous portions of land occupied by vegetation have given way to new mining sites.

While in 2015, it was observed that the mining site increased again to 466.5 $km^2$ (31.1%), also the bare surface increased to 433.8 $km^2$ (28.9%) and vegetation reduced to 601.8 $km^2$ (40.1%). The values for 2015 indicates a noticeable change detection in the vegetation cover with the vegetated land hitting its lowest ebb from an impressive 1082.0 $km^2$ in 1999 to an alarming 601.8 $km^2$ in 2015.

From the above results, it is obvious that the mining areas have increased by three (3) fold during the period under investigation. The increasing trend of the mining activities in the area of study is to the detriment of the vegetation which is evident from the Figures 3 to 5 and Table 3 above as the areas surrounding the mining sites became bare soils and also due to the fact Land-Use within the period under review in the study area is primarily mining. This serves to support Adekeye and Maponga's opinion that directly or indirectly, mining is a major factor responsible for vegetation loss [6,7].

Normalized Difference Vegetation Index was used to determine the effect of this operation on the vegetation cover in the study area. NDVI is calculated by the formula ***NDVI = (NIR – R) / (NIR + R)*** Where NIR is the reflectance in the near infrared band and R is the reflectance in the red band it value ranges from -1 to +1 [23]. Figures 6 to 8 represent NDVI values showcasing the effect that mining activities on vegetation cover in the study area.

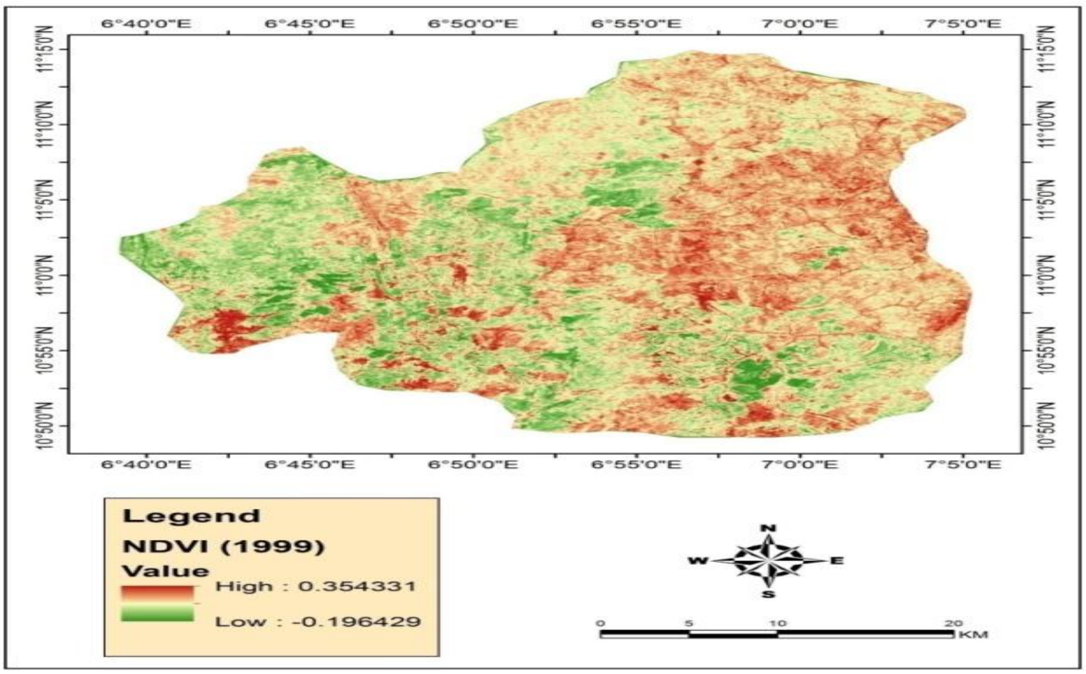


Figure 6: NDVI value of BirninGwari L.G.A. in October 1999.

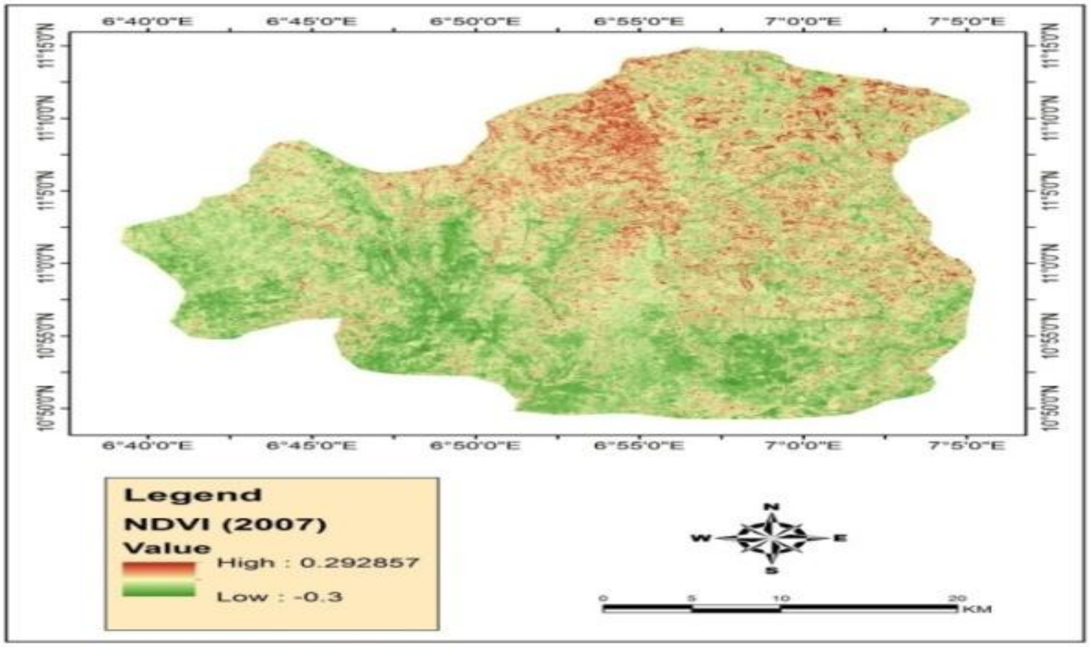


Figure 7: NDVI value of BirninGwari L.G.A. in November 2007

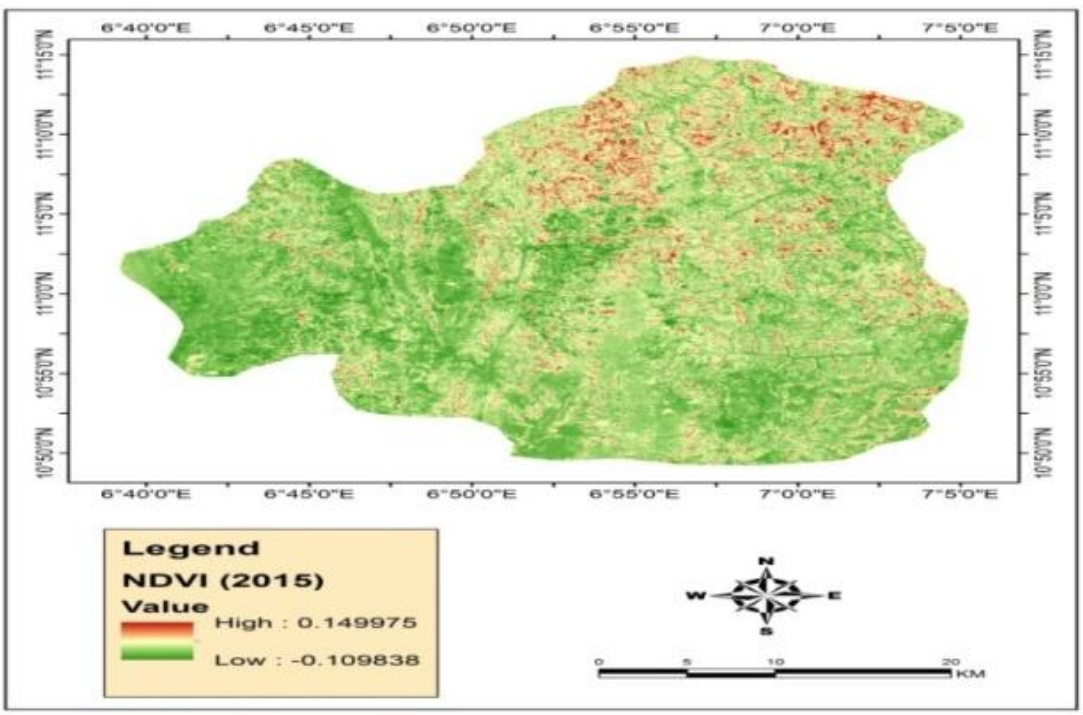


Figure 8: NDVI of BirninGwari L.G.A. in March 2015.

Figure 6 revealed that as at 1999, the area was highly vegetated (red colour) with low coverage of other land cover (green). It can be seen from the index value of NDVI that ranges from (-0.196429 to 0.354331) which indicates that at as this time the area is characterized by moderate vegetation, grasses and shrubs, the negative value shows the presence of clouds, bare surfaces, rocky outcrop, sand and water body. In 2007, the index upper limit value (-0.3 to 0.292857) reduced as shown in Figure 7. Also in 2015, the result shows a further reduction in the distribution of vegetation cover where the index value of the NDVI reduced (-0.109838 to 0.149975) by this time, the area is dominated by bare surfaces and sand with low vegetation cover (Figure 8).

Generally, the result showed that within the Sixteen (16) year period under review, there was more vegetation in 1999 but in 2015 the vegetated areas witnessed drastic reduction with little or no resemblance to its former appearance as a result of mining activity going on the study area. This was observed from NDVI values by a loss of 0.204356 (from 0.354331 to 0.149975) especially within mining areas. The effect of mining is vivid here, because before the commencement of mining, the land will need to be cleared of vegetation to allow access to the mineral bearing horizon which in-turn leads to deforestation. This finding agrees with that of Musa and Jiya's discovery of declining NDVI in response to continuous tin mining in Bukuru, Plateau State [13].

**Forecasting the Future Effects of Artisanal Mining**

Table 4 shows the various parameters used in forecasting future effects of artisanal mining on the vegetation cover of BirninGwarri Local Government Area after applying the Least Square Forecasting Statistical Tool.

Table 4: Parameters used in Forecasting Future Effects of Mining on the Study Area

| **YEAR** | **VEGETATION COVER ($Km^2$) (Y)** | **X** | **$X^2$** | **XY** |
|---|---|---|---|---|
| 1999 | 1082.00 | 1 | 1 | 1082.0 |
| 2007 | 815.30 | 2 | 4 | 1630.0 |
| 2015 | 601.80 | 3 | 9 | 1805.40 |
| **n=3** | **ΣY=2499.10** | **ΣX=6** | **$\Sigma X^2$=14** | **ΣXY=4518** |

**Using the least square equation forecasting**

$$\Sigma Y \quad = n.a + b\Sigma X \ldots\ldots\ldots\ldots\ldots....(1)$$

$$\Sigma XY = a\Sigma X + b\Sigma X^{2.} \ldots\ldots\ldots\ldots..(2)$$

2499.10 = 3a + 6b…………... (3)

4518 = 6a + 14b………………(4)

**From equation (3)**

2499.10 – 6b =3a

a = $\frac{2499.10 - 6b}{3}$……………….(5)

**Substituting (5) in (4)**

4518 = $\frac{6(2499 - 6b)}{3}$ +14b

13554 = 14994.60 – 36b + 42b

= 1313.23 – 960.4

$\mathbf{Y_{2023} = \underline{352.83\ Km^2}}$

**For the year 2031**

$Y_{2031}$ = a +bx

$Y_{2031}$ = 1313.23 – 240.1 (5)

$\mathbf{Y_{2031} = \underline{112.73\ Km^2}}$

**For the year 2039**

$Y_{2039}$ = 1313.23 – 240.1 (6)

$\mathbf{Y_{2039} = \underline{-127.37\ Km^2}}$

From the statistical analysis above it was observed that if the current mining practices in the study area persist un-curtailed, the extent of savannah vegetation in the study will further decrease even trending to negative reading with the next twenty five (25) years. This prediction tallies with that of Merrem *et al.* [14] who from descriptive analysis of remotely sensed data observed vegetated lands to be reducing in response to uncontrolled mining activities.

## CONCLUSION

The results obtained from this study have shown that over the years from 1999 to 2015 the study area has lost a great percentage (32%) of its natural vegetation cover due to the prevailing Land-Use which is artisanal mining (1082 $km^2$ to 601.8 $km^2$). Furthermore, it is forecasted that within the next 16 years, the extent of vegetated land is very likely to dip by about 18.7% to 112.73 $km^2$ if this method and pace of mining is not checked the study area.

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**CONFLICT OF INTEREST**

There was no conflict of interest during this work.

**REFERENCES**

1. Hollaway, J. (1996). Environmental Problems in Zimbabwe from Gold Panning: *CRC Perspectives, 52, 25-28.*
2. Ripley, E.A., Redmann, R.E., Crowder, A.A. & Tara, C.A. (1996). *Environmental Effects of Mining.* Delray Beach, Florida: St Lucie Press.
3. Warhurst, A. & Insor, R. (1996). Environmental Issues for Developing Countries Arising from Liberalized Trade in the Mining Industry. *Natural Resource Forum, 20 (1),*27-35.
4. Mcmahon, G., Evia, J.L., Pasco-Font, A. & Sanchez, J.M. (1999). Eds: *An Environmental study of Artisanal small and Medium Scale Mining in Bolivia, Chile and Peru World Bank Technical Paper (WTP). The World Bank, Washington, DC, Pp 429*.
5. International Union Conservation of Nature(2004). Mining: Social and Environmental Impacts. *World Rainforest Movement.* http:/www.wrm.org.uy.
6. Adekeye, J. I. (2010). The Impact of Artisanal and Illegal Mining on the Environment in Nigeria, from http://www.gisdevelopment.net/application/environment/ffm/index.htm, retrieved March 3rd, 2013.
7. Maponga, O. (1997). Small scale mining and the environment in Zimbabwe: The case of alluvial gold panning and chromite mining. In A. K. Ghose (Ed.), Small/medium scale mining Pp. 186-211.Calcutta, India: Oxford & IBH Publishing Co. PVT Ltd.
8. British Broadcasting Cooperation (BBC) news 15th September (1999). Sci/Tech UN warns of Earth crises.
9. United Nations Environmental Programme (UNEP) (1996): “Environmental and Safety

Incidents Concerning Tailings Dams and Mines". Results of a Survey for the years 1980-1996, London: *Mining Journal Research Services, 52:842-852.*

10. Global Environment Outlook (2000). United Nation Environmental Programme (UNEP). http://news.bbc.co.uk/2/hi/science/nature/447078.stm
11. Atiqur, R., Kumar. S., Fazal, S Masood, A. S. (2012). Assessment of Land use/land cover Change in the North-West District of Delhi Using Remote Sensing and GIS Techniques. *Indian Society of Remote Sensing*.40, 689–697**.**
12. Mkaanem, A.N. (2015). *Effect of Limestone Mining on Vegetation Cover in Mbayion, Gboko LGA of Benue State Nigeria, M*sc/Scie/1021/2010-2011 a thesis submitted to the School of postgraduate studies, Ahmadu Bello University, Zaria, Pp 57-58. kubanni.abu.edu.ng
13. Musa, H. D. & Jiya, S.N. (2011). An Assessment of Mining Activities Impact on Vegetation in Bukuru, Jos, Plateau State Nigeria Using Normalized Differential Vegetation Index (NDVI). *Journal of Sustainable Development.* 4(6);154- 159.
14. Merem, E. C., Twumasi, Y., Wesley, J., Isokpehi, P.,Shenge, M., Fageir, S., Crisler, M., Romorno, C., Hines, A., Hirse, G., Ochai, S., Leggett, S., Nwagboso, E. (2017). Assessing the Ecological Effects of Mining in West Africa: The Case of Nigeria, *International Journal of Mining Engineering and Mineral Processing*, 6(1), 1-19. doi: 10.5923/j.mining.20170601.01.
15. Sylvester, S.(1982). Vegetation and Soil Responses to Short-direction grazing in Fesncue grasslands. *Journals at University of Arizonia, Pp252*.
16. FADAMA 11 (2005). The average weather condition of Kaduna State
17. Woakes, M. & Bafor, B.E. (1983). Primary gold mineralization in Nigeria. In R.P. Foster, Ed GOLD '82: *The Geology, Geochemistry and Genesis of Gold Deposits. Geological Society of Zimbabwe Special Publication no.1. Balkema, Rotterdam, Pp249-260.*
18. The Administrative Map of Kaduna State showing study area modified by Onyemachi D.I (2015)**.**
19. Anderson, J. R., Hardy, E.E., J.T. & Witmer, W.E. (1976). A Land-Use and Land-Cover Classification System for Use with Remote Sensing and Data. U.S. Geological Survey Professional Paper 964, Reston, Viginia, *U.S. Geological Survey, Pp. 23.*

20. Anthony, J., Viera, M. D. & Joanne, M. G. (2005). Understanding Inter-observer Agreement: *The Kappa Statistic*. *Research Series*, 37 (5), 360-363.
21. Banga. T.R. (1988): Mechanical Estimating and Cost; Forecasting 17 , 393-394.
22. Google Map of BirninGwarri Local Government Area (2015).maps.google.com.
23. Meneses-Tover. (2011). NDVI as indicator of degradation. *Unasylva* 238, 62, 39-46.