Research Article

Multi-Temporal Analysis of Coal Mining Activity in Ankpa LGA, Kogi State using Remote Sensing

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Abstract:
This study aimed at a multi-temporal analysis of coal mining activities in Ankpa L.G.A Kogi State using Remote Sensing. Its objectives were; to ascertain the spatial extent of landuse/landcover with emphasis on coal mining activities in Ankpa L.G.A for the last 30 years (1990 – 2020) and to investigate the trend and rate of coal mining within Ankpa L.G.A between the same period. The methodology employed involved acquisition of Landsat and Sentinel-2 images, coordinates of coal mining sites. Image preprocessing was done applied to the set of images acquire to correct for effects of sun angle over a period of time, after which image classification was done, to extract LULC features from the classified images. The postclassificationcomparison technique in ERDAS Imagine was used for change detection, this was used to determine the trend and change dynamics as a result of coal mining activities between 1990 and 2020. The results showed that built up area increased by 3.42% between 1990 and 2005 and 0.56% between 2005 and 2020, while mining area increased by 3.13% between 1990 and 2005, and 3.41% between 2005 and 2020. This study is recommended as a decision-making tool for coal mining management in the study area.

Keywords: Coal Mining, Landsat, Landcover/Landuse, Remote Sensing, Sentinel-2.

I. INTRODUCTION

Mining is the extraction of valuable minerals or other geological materials from the earth, usually from an ore body, vein or coal seam. Minerals recovered by mining include based metals, precious metals, irons, uranium, coal, diamond, limestone, oil shale, rock, salt and potash. Any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory, is usually mined. Mining in a wider sense comprises extraction of any non-renewable resources (Ibrahim et al, 2010). Warhurst (1999) asserted that the term “mining” covers all aspect of metal production, including mine development, extraction, smelting, re-mining and waste management. Hence, mining is regarded as the process through which man wins minerals from the earth and turns them into valuable goods for his use. The process of mining according to Dung-Gwon (2007) among others involves; exploration, exploitation (extraction), processing, re-mining, waste management, mine closure and post-mining activities.

The adverse environmental impact of mining activities on the environment is well documented (David and Glenn, 2006; Varinder et al., 2016; Nuray et al., 2011Warhusr, 1994). Particular attention has been directed towards the impacts of large scale and small-scale coal mining activities on environmental contamination. While the land degradation caused by the coal mining is pronounced, chemical contamination from the coal extraction process imposes a double burden on the environment, with harmful health implications for mining communities and people residing in close proximity to such activities (Yelpala, 2004). Coal mining in Kogi State especially in Ankpa L.G.A, has triggered a lot of spatial landuse changes dynamics. The increase in coal mining activities throughout the years has posed problems for Ankpa L.G.A. There are problems such as deforestation as a result of coal mining activities in Ankpa L.G.A. To solve these problems or at least provide a decision support system on which planning can be based on, a deeper understanding of the concepts underlying coal mining activities in Ankpa L.G.A can assist toward formulating appropriate policies for environmental management, and thus, lessening the negative impacts while maximizing the positive impacts (Camara et al., 1997).

To understand the temporal dynamics of coal mining in Ankpa L.G.A, a broad analysis of the spatial trends of mining activities between 1990 and 2020 would help in addressing the problems associated with coal mining in the study area. This will play a key role in planning and becomes crucial especially when data on mining activities are scarce. Remote Sensing (RS) and Geographic Information System (GIS) are effective tools for analyzing the effects coal mining in Ankpa L.G.A.

The collection of remotely sensed data facilitates the synoptic analyses of coal mining activities over time; such data also provide an important link between intensive conservation and management of the environment. With the collection of these spatial data for a different time period, it is then possible to monitor, manage the effects of coal mining in Ankpa L.G.A. The use of remotely sensed data in this research can provide a detailed insight into the spatial extents of coal mining activities with emphasis on its effects on the environment in the past, present and also the future. Hence this study intends to investigate and analyze the effect of coal mining activities on the environment within Ankpa L.G.A between 1990 and 2020 with a view to detecting the change that has taken place and also to ascertain the trend within the last 30 years.
II. MATERIALS AND METHOD

2.1. Study Area
Ankpa is a Local Government Area in Kogi State, Nigeria. Its headquarters are in the town of Ankpa on the A233 highway in the west of the area. It is located between latitudes 7°2′00″N and 7°3′00″N and longitudes 7°30′00″E and 7°50′00″E see figure 1.1. Ankpa L.G.A has an area of 1,200 km² and a population of 267,353 at the 2006 census. Ankpa LGA has two main rock types namely: basement complex rock of the Precambrian age in the western half of the state and extending slightly eastwards beyond the lower Niger valley and older sedimentary rocks in the eastern half. The various sedimentary rock groups extend along the bank of rivers Niger and Benue and southeast wards through Enugu and Anambra states to join the Udi plateau. The study area’s mineral deposits are iron ore, mica, marble, lime stone, coal, gold, kaolin, tantalite, feldspar, quartz, dolomite, columbite, cassiterite, talc, gypsum gemstone. Agricultural produce is yam, cassava, rice, maize, guinea corn, cocoa, coffee, cashew, fish and groundnut. The study Area has an annual rainfall of between 1,100mm and 1,300mm. The rainy season lasts from April to October. The dry season, which lasts from November to March is very dusty and hot. The alluvial soils along the valleys of the rivers are sandy, while the adjoining laterite soils are deeply weathered and grey or reddish in colour, sticky and permeable. The vegetation in the study area (Lokoja) is guinea savannah or parkland savannah belt with tall grasses and some trees. The trees which grow in clusters are up to six meters tall, interspersed with grasses which grow up to about three meters. The different types of vegetation are, however, not in their natural luxuriant state owing to the careless human use of the forest and the resultant derived deciduous and savannah vegetation.

![Figure 1.0. Map of Study Area](http://ijesc.org/)

2.2 Method
The study utilized secondary data to identify the effects of coal mining on greenhouse emissions in Ankpa LGA. Landsat TM, ETM+ and OLI images were obtained from (USGS) [http://earthexplorer.usgs.gov/] for 1990, 2005 and 2020 and 2017 with a spatial resolution 30m. All of its bands were used for this study.

2.2.1. Method

i. Image Preprocessing
The Landsat 5 thematic mapper for the year 1990, Landsat 7 enhanced thematic mapper for 2005 and Landsat 8 operational land imager for 2020 were radiometrically and geometrically corrected using the approach by Orimoloye et al, (2018).

ii. Image Classification
In order to examine the LULC distribution, a land cover classification scheme by Anderson et al, (1967) was adopted, this resulted in the following class features: vegetation, riparian vegetation, rocky area, bare surface, built up area and mining areas using supervised image classification. Ground truthing was carried out to collect sample data for accuracy assessment using random sampling technique.

iii. Trend Analysis
Having being used in many studies, Long et al (2007)’s method of calculating and comparing the area of the resulting landcover/landuse types of each year by was adopted for data analysis. The comparison of the land cover/land use statistics assisted in identifying the percentage change, trend and rate of change between 1990 and 2020. In achieving this table was prepared showing the areas and percentage change for each year measured against each other. To determine the rate of change of landcover/landuse change, the year period 1990-2020 was divided into two sub-periods 1990 – 2005 and 2005 - 2020 and then compared against each other.The comparative analysis in landcover/landuse change focuses on the two sub-periods and
the spatial distribution of the average (annual) rate of land cover/land use change between the two periods, (Long et al., 2007). Percentage change to determine the trend of change was calculated by dividing the observed change by the sum of the area of the particular landcover/landuse type in that period multiplied by 100

\[
\text{(Trend) \% change} = \frac{\text{Observed change}}{\text{Total Area}} \times 100
\]

Total Area = Sum of the total area of both years = (∑ area in 1990 and 2005, ∑ area in 2005 -2020)
The annual percentage rate = Trend divided by N. where N= (15 years).
A trend percentage with a positive value means that the landcover/landuse type has increased over the period of years while a negative value shows a decrease in the landcover/landuse type over a period of time.

3.0 RESULTS

3.1 Landcover/landuse Analysis of Ankpa LGA from 1990 to 2020
The landcover/landuse analysis of Ankpa between 1990 and 2020 is displayed in Table 3.1 and summarily discussed below. In 1990, the landuse/landcover distribution of Ankpa LGA in showed that vegetation had a percentage coverage of 41% and an area of about 520 km².
Riparian Forest had 15.56% and a coverage area of 196 km². Rocky area had 14.29% and a coverage area of 180.55 km², bare surface had 19.51% and a coverage area of 246.60 km² built up area had 9.45% with area coverage of 119.47 km², while mining area had 0.04% with area coverage of 0.51 km². In 2005, built up area grew from a percentage coverage of 9.45% to 29.42%, to an area of about 371.79 km², followed by vegetation decrease from a percentage coverage of 41.15% to 23.48% arriving at a coverage area of 296.76 km², riparian Forest had a slight decrease from a percentage coverage of 15.56% to 13.90% and 17.75% respectively, having a final coverage area of 175.68 km² and 224.29 km² respectively. Lastly, mining area increased from had 0.04% to 0.11% to an area coverage of 1.42 km².
Lastly, in 2020, built up area further increased to 34.81% percentage coverage to an area of about 439.95 km², followed by further vegetation decrease to 21.99% with a coverage area of 277.92 km² while riparian forest decreased to 14.79% with a coverage area of 186.58 km². Rocky area and bare surface both decreased to a percentage coverage of 12.26% and 15.83% to a coverage area of 154.91 km² and 199.99 km² respectively. Lastly, mining area also increased from had 0.11% to 0.35% to an area coverage of 4.39 km².

<table>
<thead>
<tr>
<th>Year</th>
<th>Class Name</th>
<th>Area</th>
<th>Percentage</th>
<th>Area</th>
<th>Percentage</th>
<th>Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Vegetation</td>
<td>520.00</td>
<td>41.15</td>
<td>296.76</td>
<td>23.48</td>
<td>277.92</td>
<td>21.99</td>
</tr>
<tr>
<td>2005</td>
<td>Riparian Vegetation</td>
<td>196.61</td>
<td>15.56</td>
<td>193.81</td>
<td>15.34</td>
<td>186.58</td>
<td>14.76</td>
</tr>
<tr>
<td>2020</td>
<td>Rocky Area</td>
<td>180.55</td>
<td>14.29</td>
<td>175.68</td>
<td>13.90</td>
<td>154.91</td>
<td>12.26</td>
</tr>
<tr>
<td></td>
<td>Bare Surface</td>
<td>246.60</td>
<td>19.51</td>
<td>224.29</td>
<td>17.75</td>
<td>199.99</td>
<td>15.83</td>
</tr>
<tr>
<td></td>
<td>Built Up Area</td>
<td>119.47</td>
<td>9.45</td>
<td>371.79</td>
<td>29.42</td>
<td>439.95</td>
<td>34.81</td>
</tr>
<tr>
<td></td>
<td>Mining Area</td>
<td>0.51</td>
<td>0.04</td>
<td>1.42</td>
<td>0.11</td>
<td>4.39</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1263.75</td>
<td>100.00</td>
<td>1263.75</td>
<td>100.00</td>
<td>1263.75</td>
<td>100.00</td>
</tr>
</tbody>
</table>
3.2 Trend Analysis

In this study, vegetation lost a total area of $-223.24\text{km}^2$ between 1990 and 2005, and also lost $-18.84\text{km}^2$ between 2005 and 2020 making it a total of $-242.08\text{km}^2$ lost by vegetation between 1990 and 2020. Riparian forest lost a total area of $-2.80\text{km}^2$ between 1990 and 2005, and also lost $-7.23\text{km}^2$ between 2005 and 2020 making it a total of $-10.03\text{km}^2$ lost by riparian forest between 1990 and 2020. Rocky area lost a total area of $-4.88\text{km}^2$ between 1990 and 2005, and also lost $-20.77\text{km}^2$ between 2005 and 2020 making it a total of $-25.65\text{km}^2$ lost by rock surfaces between 1990 and 2020. Bare surface lost a total area of $-22.31\text{km}^2$ between 1990 and 2005, and also lost $-24.30\text{km}^2$ between 2005 and 2020 making it a total of $-46.61\text{km}^2$ lost by bare surface between 1990 and 2020. Built up gained a total area of $252.32\text{km}^2$ between 1990 and 2005, and also gained $68.17\text{km}^2$ between 2005 and 2020 making it a total of $320.48\text{km}^2$ gained by built up area between 1990 and 2020. Lastly, mining area gained a total area of $0.91\text{km}^2$ between 1990 and 2005, and also gained $2.97\text{km}^2$ between 2005 and 2020 making it a total of $3.88\text{km}^2$ gained by mining area between 1990 and 2020, see figure 3.3 for more details.

![Figure 3.2. Landcover/landuse map of Ankpa LGA (a) 1990, (b) 2005 and (c) 2020](image)

**Figure 3.2. Landcover/landuse map of Ankpa LGA (a) 1990, (b) 2005 and (c) 2020**

Also, for more insight, vegetation had a total area of $816.76\text{km}^2$ between 1990 and 2005, and also lost $574.86\text{km}^2$ between 2005 and 2020, riparian forest had a total area of $390.42\text{km}^2$ between 1990 and 2005 and $380.40\text{km}^2$ between 2005 and 2020, rocky area had a total area of $356.23\text{km}^2$ between 1990 and 2005 and $330\text{km}^2$ between 2005 and 2020, bare surface had a total area of $470.90\text{km}^2$ between 1990 and 2005 and $424.28\text{km}^2$ between 2005 and 2020. Built up had a total area of $491.26\text{km}^2$ between 1990 and 2005 and $811.74\text{km}^2$ between 2005 and 2020. Lastly, mining area had a total area of $1.93\text{km}^2$ between 1990 and 2005 and $5.81\text{km}^2$ between 2005 and 2020. Trend of change of Landcover/landuse of Ankpa LGA Between 1990 and 2020 was given as $-27.33\%$ for vegetation between 1990 and 2005, and $-3.28\%$ between 2005 and 2020. The trend of change for riparian forest was given as $-0.72\%$ between 1990 and 2005 and $-1.90\%$ between 2005 and 2020. The trend of change for rocky area was given as $-1.37\%$ between 1990 and 2005 and $-6.28\%$ between 2005 and 2020. The trend of change for bare surface was given as $-4.74\%$ between 1990 and 2005 and $-5.73\%$ between 2005 and 2020. The trend of change for built up area was given as $51.36\%$ between 1990 and 2005 and $8.40\%$ between 2005 and 2020. Then lastly, the trend of change of mining area was given as $46.96\%$ between 1990 and 2005, and $51.15\%$ between 2005 and 2020, see figure 3.4.

![DINERENCE IN AREA](image)

**Figure 3.3. Difference in area between 1990 and 2020**

<table>
<thead>
<tr>
<th></th>
<th>1990-2005</th>
<th>2005-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>-223.24</td>
<td>-2.6</td>
</tr>
<tr>
<td>Riparian forest</td>
<td>-2.8</td>
<td>-4.80</td>
</tr>
<tr>
<td>Rocky Area</td>
<td>-4.88</td>
<td>-22.31</td>
</tr>
<tr>
<td>Bare Surface</td>
<td>-22.31</td>
<td>252.32</td>
</tr>
<tr>
<td>Built Up Area</td>
<td>252.32</td>
<td>0.91</td>
</tr>
<tr>
<td>Mining Area</td>
<td>-18.84</td>
<td>-7.23</td>
</tr>
<tr>
<td></td>
<td>-20.77</td>
<td>-24.3</td>
</tr>
<tr>
<td></td>
<td>68.17</td>
<td>2.97</td>
</tr>
</tbody>
</table>
The annual rate of change of Landcover/landuse of Ankpa LGA Between 1990 and 2020 was given as -1.82% for vegetation between 1990 and 2005, and -0.22% between 2005 and 2020. The trend of change for riparian forest was given as -0.05% between 1990 and 2005 and -0.13% between 2005 and 2020. The trend of change for rocky area was given as -0.09% between 1990 and 2005 and -0.42% between 2005 and 2020. The trend of change for bare surface was given as -0.32% between 1990 and 2005 and -0.38% between 2005 and 2020. The trend of change for built up area was given as 3.42% between 1990 and 2005 and 0.56% between 2005 and 2020. Then lastly, the trend of change of mining area was given as 3.13% between 1990 and 2005, and 3.41% between 2005 and 2020, see figure 3.5.

This indicates that between 1990 and 2020, all landuse/landcover classes deceased except for built up area and mining area

4.0 CONCLUSION

This study successfully analyzed coal mining activities and its subsequent effect on greenhouse emissions in Ankpa LGA, Kogi State. Between 1990 and 2020. The methodology employed involved acquisition of Landsat 5 thematic mapper, Landsat 7 enhanced thematic mapper plus, Landsat 8 Operational Land Imager, Sentinel-2 and coordinates of coal mining sites. Image preprocessing was done applied to the set of images acquire to correct for effects of sun angle over a period of time, this is because the multi temporal data were being used, after which image classification was done, to extract LULC features from the classified images. The post classification comparison technique in ERDAS Imagine was used for change detection. This method is the most intuitive change detection method. This was used to determine the trend and change dynamics as a result of coal mining activities between 1990 and 2020. The results obtained here indicated that between 1990 and 2020, all landuse/landcover classes deceased except for built up area and mining area

5.0. REFERENCE


