Object-Based Approach for Landuse/Landcover Mapping of Makurdi Area of Benue State, Nigeria using High Resolution Satellite Imagery

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Abstract:
The tremendous development in Makurdi metropolis has been fully expressed in the form of unprecedented urbanization since it is an economical viable city known for its arable land for agriculture and other activities. The increasing rate of urbanization has created many social and environmental problems as a result of man and his interactions with the environment. There is lack of up to date land cover maps of Makurdi Metropolis, a current landcover map is needed to accurately take decision on environmental and urban growth. Therefore, this study aimed to carry out a Land use/Land cover Mapping of Makurdi Areas in Benue State, using Object-Based approach with a view to generate spatial information needed for urban management. Its objectives were to process, clarify and analyze high resolution imagery of the study area, generate spatial information of Makurdi Urban Areas using segmentation-based classification method and relate them to urban Management in Makurdi Area and to access the accuracy results of land use/land cover maps generated. The methodology adopted in the study were data acquisition using QuickBird imagery. Georeferencing was done, after which the image was classified using object-based classification algorithm in eCognition software. The results indicated that the land use and development in the study area was restricted to the low-lying areas, most especially Wadata quarters, all these provided the framework for the haphazard development of the city. Thus, a good number of the land use problems in Makurdi were caused by lack of proper planning and monitoring of development. The research recommended that further studies on object-based classification should be employed for the whole Benue State, landuse pattern in Makurdi town should be improved upon for preservation of ecosystem and concerned environmental scientists should encourage the development of greenery in Makurdi town to improve cross ventilation to avert excessive heat in the town. In conclusion, various steps of this research were properly applied, in-terms of data capture, database design, database creation and product presentation, which becomes very necessary to find out the best method for analyzing land use and land cover pattern of the study area using remote sensing method.

Keywords: Object-based Classification, eCognition, Landuse/Landcover.

I. INTRODUCTION

The land use and land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land-use and Land-cover information is essential for urban planning and management. Due to immense agricultural activities and demographic pressures on land, land is becoming a scarce commodity; hence information on land use / land cover and possibilities for their optimal use is essential and relevant to the selection, planning and implementation of land use / land cover scheme to meet the increasing demands for basic human needs and welfare [1]. This information also assists in monitoring the dynamics of land use / land cover, resulting from changing demands of increasing population. Land use and land cover change have become a central component in current strategies for managing natural resources and monitoring environmental changes. Land use and land cover changes, plays an important role in global environmental change. It is one of the factors affecting sustainable development and human response to global changes. The scientific community has now come to recognize diverse roles of land use and land cover changes [2]. Consequently, the need for understanding of land use / land cover changes has been increasingly recognized in global environmental research [3]. The extent and rates of change in land cover of some land are known with some certainty. According to [2], most of the earth’s surface is already modified, except those areas that are peripheral in location or are fairly inaccessible. LULC studies are multidisciplinary in the nature, and thus the participants involved in such works are numerous and varied, ranging from wildlife and conservation foundations to government researchers and forestry companies. Regional government agencies have an operational need for land cover inventory and land use monitoring, as it is within their mandate to manage the natural resources of their respective region. In addition, to facilitate sustainable management of land, LULC information may be used for planning, monitoring, and evaluation of development industrial activities of reclamation. Detection of long-term changes in land cover may reveal a response to shift in local or regional climatic conditions, the basis of terrestrial global monitoring. Rapid urban development and increasing land use changes due to population and economic growth in selected landscapes is being witnessed of late in Makurdi- Nigeria and other developing countries. The cities are developing in all directions resulting in large scale urban sprawl and changes in urban land use. The assessment of these changes depends on the source, the definition of the land use type, the spatial groupings and the data sets used. [4] opined that, remote sensing techniques are particularly suitable for the production of land use and land cover maps. There is an urgent need to accurately describe land use changes for planning and suitable
management. Remote sensing is gaining importance as a vital tool in the analysis and integration of spatio-temporal data. Remote sensing images have often been used to aid locating business or public facilities and provide unique perspective on how cities evolve. It has the ability to discriminate between rural uses (farming and pasture forests) and urban uses (residential, commercial and recreational). Remote sensing methods can be employed to classify types of land use over large area in practical, economical and repetitive fashion. The tremendous development in Makurdi metropolis has been fully expressed in the form of unprecedented urbanization since it is an economical viable city known for its arable land for agriculture and other activities. The increasing rate of urbanization has created many social and environmental problems as a result of man and his interactions with the environment. The available information on the development Makurdi Metropolis is insufficient. This makes decision making process complex and less transparent. There are no landcover/landuse maps currently available to correctly evaluate the status in landcover/landuse Makurdi Metropolis. Therefore, there is need to map the pattern of existing land use/land cover classification of the study area with high resolution image and also to produce an up-to-date land use/land cover database for decision makers.

II. STUDY AREA

Benue State lies within the lower river Benue in the middle belt region of Nigeria. Its geographic coordinates lies between Longitude 7° 47’ E to 10° 0’ E and Latitude 6° 25’ N to 8° 8’ N. Benue State lies within the lower river Benue trough in the middle belt region of Nigeria and shares boundaries with five other states namely: Nasarawa State to the north, Taraba State to the east, Cross-River State to the south, Enugu State to the south-west and Kogi State to the west. The state also shares a common boundary with the Republic of Cameroon on the south-east.

III. METHODOLOGY

This section outlines the proposed methods that were used for the research work. These include: data requirements, acquisition, data processing, and analysis. Figure 3.1 shows the sequence of work flow that was followed in the course of carrying out this research.

A. Data Requirements

These datasets were obtained from field work exercise to validate satellite data. Field data capturing was based on basic survey principles and techniques. A handheld Garmin GPSMAP 76c receiver was employed in the traverse for point positioning. Also, A420 Cannon power shot Digital Camera was used to picture the area, so as to aid better visual appreciation and spatial analysis of the area, while the secondary datasets were obtained from already existing data. The software used were: eCognition developer 64, used for object-based classification, ArcMap 10.3 used for landcover/landuse map production and MS Office for project report compilation.

Data used in this research include:

i. Satellite Imagery (QuickBird 0.6m resolution) of the study area was acquired from the Directorate of Army Mapping and Survey Unit (DAMS), Owode – Yewa, Ogun State.

ii. Coordinates of control points and other points of interest.

iii. Attribute Data of points of interest.

iv. The coordinates of the study area were acquired using hand held GPS receiver for the training data non-spatial (attribute) data describing the characteristics of features of interest were collected on ground.

B. Data Pre-Processing

The pre-processed raster (QuickBird) image initially on Reference System WGS 84 was converted to Projected Reference System UTM Minna datum. The analogue map was converted to digital format through the process of scanning. The study area was framed and extracted using the input criteria of upper and lower coordinates (Easting and Northing). The resolution of the QuickBird is 0.6 m in multi-spectral band. To achieve desirable (higher) image data quality to be used for geo-registration and feature digitizing, a clipped QuickBird image of the study area was inserted into ArcMap 10.3 environment to produce image map (Figure 3.2). The image reprocessing module of this enabling software was used to reprocess the image for higher visual quality.
C. Image Segmentation

Segmentation is always the first step of any process within a defined area as it generates the image objects on which the classification process was performed. The important part is for the segmentation process to identify objects which are representative of the features to be classified. As with all work within Definiens Developer the first step is to create a project containing all the datasets required for the study. A feature extraction tool was used to identify individual regions with homogeneous land use/cover type. In order to investigate the effect of shape parameter on image object creation, values were varied between 0.1 and 0.9 with an equal step of 0.2 in that scale was set to 20 and compactness was kept constant as 0.5 for all parameter combinations at this stage, the Multiresolution Segmentation Algorithm was used. These segmentation parameters ensured a good delineation of individual objects representing the main land use/cover types in the area. Given the high spatial resolution of the images, the objects extracted initially were merged using a merging \((\lambda)\) threshold to iteratively merge adjacent segments based on a combination of the spectral and spatial information contained in the extracted segments [5]. This process helped to reduce over-segmentation by integrating small objects into larger homogeneous segments.

D. Delineation of Land Use Land Cover Classes

The classification process classified all objects in the entire image based on the selected samples and the defined statistics. It classified each object based on their closeness to the training set. Standard Nearest Neighbor Statistic was applied, it is a powerful (and little known) approach to create land cover classification. The sample editor was used to assign classes from training site. The Sample Editor provides a visual comparison of two classes using a range of selected features. The thresholds were determined by training the classification with the area and perimeter-area characteristics of the classes observed in the field.

E. Design and Creation of Digital Spatial Database

Classified datasets were converted to vector format and incorporated into a GIS environment (figure 3.6). Taking advantage of the increasingly stronger linkage between Remote Sensing and GIS, which provides data integration capabilities and map overlay techniques [6]. Various GIS processing techniques were applied to improve the classification accuracy. Given the large number of resulting polygons in each classified dataset; a GIS tool aggregate was applied to combine same class polygons within 5, 10, 20 and 40m threshold distances. Based on the best performing aggregate parameter, the elimination tool was used to merge...
polygons smaller than 3, 18, 72 and 288m² and neighboring polygons with largest shared border. After selecting the best performing eliminating parameter, smooth line tool was implored to improve the overall cartographic appearance of the polygons’ boundaries. Finally, the features that were not detected were edited and corrected manually through the process.

Figure 3.6: Classified datasets converted to vector format in a GIS environment.

IV. RESULTS

Technological advances and increasing availability of high-resolution satellite image offer the potential for more accurate land cover classifications and pattern analyses, which could greatly improve the detection and quantification of land cover change for conservation. The High-resolution satellite image of the Study Area (Makurdi) shows through the visual interpretation that Makurdi City has some potential infrastructures. The Classes of road network and other land uses feature were captured and evaluate through the satellite imagery.

A. Evaluation of Spatial Information of Makurdi Urban through Object Based Classification

Analysis of the output Figure 4.1 below shows the outcome of the original image segmentation using threshold value. This threshold value captured almost all building rooftops as well as other non-building surfaces that have high spectral intensities.

Table 4.1. Assessment of Landuse Dataset of the study Area

<table>
<thead>
<tr>
<th>ewCODE</th>
<th>Classes</th>
<th>Perimeter (M)</th>
<th>Area (Sqm)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Old Building</td>
<td>178747.900</td>
<td>121939.700</td>
<td>8.330</td>
</tr>
<tr>
<td>2</td>
<td>Red Roof</td>
<td>33747.8200</td>
<td>44553.8200</td>
<td>3.040</td>
</tr>
<tr>
<td>3</td>
<td>Blue Roof</td>
<td>80127.1500</td>
<td>44517.510</td>
<td>3.040</td>
</tr>
<tr>
<td>4</td>
<td>White Roof</td>
<td>23122.6500</td>
<td>22511.290</td>
<td>1.540</td>
</tr>
<tr>
<td>5</td>
<td>Green Roof</td>
<td>52857.8600</td>
<td>46206.250</td>
<td>3.158</td>
</tr>
<tr>
<td>6</td>
<td>Open Ground</td>
<td>119941.100</td>
<td>93013.510</td>
<td>6.360</td>
</tr>
<tr>
<td>7</td>
<td>Tarred Road</td>
<td>396281.200</td>
<td>364144.900</td>
<td>24.880</td>
</tr>
<tr>
<td>8</td>
<td>Paved Ground</td>
<td>949101.600</td>
<td>64119.840</td>
<td>4.380</td>
</tr>
<tr>
<td>9</td>
<td>Vegetation</td>
<td>213988.500</td>
<td>203856.500</td>
<td>36.640</td>
</tr>
<tr>
<td>10</td>
<td>Trees</td>
<td>309687.800</td>
<td>332417.200</td>
<td>22.710</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>171938.100</td>
<td>146352.700</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Measuring current conditions and how they are changing can be easily achieved through land cover mapping, a process that quantifies current land resources into a series of thematic categories, such as forest, water, and paved surfaces. Land management and land planning in Makurdi requires a knowledge of the current state of the landscape. The landcover/landuse map in figure 4.1 and the details in figure 4.2 facilitates the understanding of current land cover and how it is being used, along with an accurate means of monitoring change over time, is vital to agency responsible for land management. The Histogram in Figure 4.2 below shows that the Tarred Road and Vegetations are the highest Classes in the study area.

Figure 4.2. Histogram of land use classes in the study area.

The detail analysis of the Landuse in Figure 4.3 shows that building occupied 19.11% of the study area, this including (Old roof, Red Roof, blue roof, white Roof and green Roof), open ground is 6.36%, Road 33.51% Paved Ground 4.38, Vegetation 36.64%, as presented in the table 4.2.

Table 4.2. Summary of land use classes of the study area

<table>
<thead>
<tr>
<th>S/n</th>
<th>Classes</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Building</td>
<td>19.11</td>
</tr>
<tr>
<td>2</td>
<td>Open Ground</td>
<td>6.36</td>
</tr>
<tr>
<td>3</td>
<td>Tarred Road</td>
<td>33.51</td>
</tr>
<tr>
<td>4</td>
<td>Paved Ground</td>
<td>4.38</td>
</tr>
<tr>
<td>5</td>
<td>Vegetation</td>
<td>36.64</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
Figure.4.3. Histogram showing building inventory in the study area.

The statistical table of the Building datasets of the study area shows that the Old Roof is 8.33% while Red Roofing 3.04%. Blue Roofing accounted for 3.04%, White for 1.54% while Green accounted for 3.16%, the other landuse cover also were also evaluated such as Open Ground 6.36%, Paved Ground 4.38% and Trees 22.71%. The Roads were also assessed through evaluation of Tarred Road 24.88%.

B. Query

A query layer is a layer or stand-alone table that is defined by a SQL query. Query layers allow both spatial and nonspatial information stored in a DBMS to be easily integrated into GIS projects within ArcMap. Since query layers are using SQL to directly query database tables and views, spatial information used by a query layer is not required to be in a geodatabase. When working in ArcMap, you create query layers by defining a SQL query. The query is then run against the tables and views in a database, and the result set is added to ArcMap as a layer or stand-alone table (depending on the query). The query is executed every time the layer is displayed or used in ArcMap.

This allows the latest information to be visible without making a copy or snapshot of the data and is especially useful when working with dynamic information that is frequently changing. The query layers functionality works with any of the DBMSs supported by ArcGIS. Query layers allow ArcMap to integrate data from geodatabases as well as from DBMSs. Therefore, query layers can quickly integrate spatial and nonspatial information into GIS projects independently of where and how that information is stored. In this research, three major queries were performed which are

i. Query by identification

ii. Query by attribute

iii. Query by location

1) Query by Identification

The query by identification in ArcGIS10.3, is simple method of identifying the feature in a GIS environment. In this study an area of interest was target by using the identification tool to detect the spatial information of the area. The result reveal that the area was covered by trees, grasses and a blue roof building as shown in the figure 4.4.

2) Query by Attribute

The query by attribute is a simple method for selection of features in GIS environment using information from attribute table. In this research, a selection by attribute was performed to highlight the churches. Out of 25 features in the study area, the result reveal that there are three churches in the study area. See figure 4.5.

3) Query by Location

The query by location of features is done based on feature location as related to features in another layer. In this research, a query was performed to select features that are adjacent to other features. For example, old buildings that intercept with the road networks were highlighted, and the result shows that Five (5) out of Twenty-Two 22 road networks in the study area were highlighted. See figure 4.6.
C. Accuracy Assessment

The table below shows the accuracy assessment of the Object based classification of the study area. The frequency of the same classes in diagonal line are the corrected classified feature while other are commission and omission error. The overall accuracy is 79%. Rows correspond to classes in the ground truth map (or test set).

**Accuracy** (also known as producer's accuracy): It is the fraction of correctly classified pixels with regard to all pixels of that ground truth class. For each class of ground truth pixels (row), the number of correctly classified pixels is divided by the total number of ground truth or test pixels of that class.

**Reliability** (also known as user's accuracy): The figures in row Reliability (REL) present the reliability of classes in the classified image; it is the fraction of correctly classified pixels with regard to all pixels classified as this class in the classified image. For each class in the classified image (column), the number of correctly classified pixels is divided by the total number of pixels which were classified as this class.

The Average Accuracy is calculated as:

\[
\text{Average Accuracy} = \frac{\text{sum of the accuracy figures in column accuracy}}{\text{the number of classes in the test set}}
\]

The Average Reliability is calculated as:

\[
\text{Average Reliability} = \frac{\text{sum of the reliability figures in column reliability}}{\text{the number of classes in the test set}}
\]

The Overall Accuracy is calculated as:

\[
\text{Overall Accuracy} = \frac{\text{total number of correctly classified pixels}}{\text{total number of test pixels}}
\]

<table>
<thead>
<tr>
<th>Classes</th>
<th>Old Building</th>
<th>Red Roof</th>
<th>Blue Roof</th>
<th>White Roof</th>
<th>Green Roof</th>
<th>Open Ground</th>
<th>Tarred Road</th>
<th>Untarred Road</th>
<th>Paved Ground</th>
<th>Grasses</th>
<th>Trees</th>
<th>Total</th>
<th>Producer's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Building</td>
<td>96</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>15</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>134</td>
<td>71.64</td>
</tr>
<tr>
<td>Red Roof</td>
<td>1</td>
<td>47</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51</td>
<td>92.16</td>
</tr>
<tr>
<td>Blue Roof</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>52</td>
<td>63.46</td>
</tr>
<tr>
<td>White Roof</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>26</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>81.25</td>
</tr>
<tr>
<td>Green Roof</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>35</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>47</td>
<td>74.47</td>
</tr>
<tr>
<td>Open Ground</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>78</td>
<td>4</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>78.00</td>
</tr>
<tr>
<td>Tarred Road</td>
<td>7</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>326</td>
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<td>6</td>
<td>7</td>
<td>12</td>
<td>391</td>
<td>83.38</td>
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<tr>
<td>Untarred Road</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>16</td>
<td>105</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>139</td>
<td>75.54</td>
</tr>
<tr>
<td>Paved Ground</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>68.00</td>
</tr>
<tr>
<td>Grasses</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>176</td>
<td>23</td>
<td>217</td>
<td>81.11</td>
</tr>
<tr>
<td>Trees</td>
<td>6</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>31</td>
<td>307</td>
<td>383</td>
<td>80.16</td>
</tr>
<tr>
<td>Total</td>
<td>122</td>
<td>56</td>
<td>64</td>
<td>31</td>
<td>57</td>
<td>99</td>
<td>400</td>
<td>141</td>
<td>53</td>
<td>218</td>
<td>355</td>
<td>1596</td>
<td>849.16</td>
</tr>
<tr>
<td>User's Accuracy</td>
<td>78.69</td>
<td>83.9</td>
<td>51.5</td>
<td>6</td>
<td>83.87</td>
<td>61.40</td>
<td>78.79</td>
<td>81.50</td>
<td>74.47</td>
<td>64.15</td>
<td>80.73</td>
<td>86.4</td>
<td>825.5</td>
</tr>
</tbody>
</table>

Average Accuracy = 77.20%
Average Reliability= 75.05%
Overall Accuracy = 79.00%

V. CONCLUSION

The aim of this study is to carry out a Land use/Land cover Mapping of Makurdi Areas in Benue State, using Object-Based approach with a view to generating spatial information for Urban Management. The specific objectives are to process, clarify and analyse high resolution imagery of the study area, generate spatial information of Makurdi Urban Areas during the image classification procedure through the use of segmentation-based classification method and relate them to urban Management in Makurdi Area. The results reveal the pattern of land use in part of Makurdi City. The research indicates that the land use and development in the study has been restricted to the low-lying areas, most especially Wadata quarters. However, there is virtually no master plan for the development of Makurdi, no land use zoning scheme is adopted and individual claim to land is still very high. All these provided the framework for the haphazard development of the city. Thus, a good number of the land use problems in Makurdi are caused by lack of proper planning and monitoring of development. The above research finding is that the land use activities and land covers in the study area are un-controlled. The imbalance in land use/land cover classification structure of the study area is vivid. Some land uses are over represented at the expense of others. For instance, all the various classified roofs resulted to 19.11% of the built-up area. Others such as tarred road 24.88%, un tarred road 8.63%, paved ground land use 4.38%, etc. Among the important land use problems consequent upon this development is the method of handling and record keeping of land use / land cover information. As a result of this, it becomes very necessary to find out the best method for analyzing land use and land cover pattern of the study area using remote sensing method. Remote Sensing application is a very adequate method as applied to the mapping and analysis of land use/land cover of the study area. It makes use of recent data (Remote Sensing) that are adequate and up-to-date analytic approach using appropriate software like eCognition for image classification.
ArcMap for georeferencing and vectorization and thematic map, database creation and analysis. This study is important in the sense that there are no records for land use / land cover of the study area that saddled with the responsibility of providing land use/land cover maps. As a result of this short coming, it is therefore imperative that such studies should be undertaken to make available such maps which are veritable tools for land management, planning and implementation in order to create sustainable environment. This research will show that with enough capital and man power, remote sensing and GIS techniques can be applied at a nationwide scale to create a digital land use and land cover database for the Makurdi to enhance sustainable development and management of the state’s scarce resources. The products from this research work will be of immense assistance to the state government of the study area and the nation in general in terms of adequate and proper planning regarding the use of land. The composite plan will serve as a guide to the inhabitants and visitors in the study area while the decision makers both government and individuals will have better understanding and information of the occupied lands, unused lands, open or vacant lands, different land cover types available in the area and so on for effective land management. The ultimate goal of land use/land cover planning and management is to make an urban environment conducive for human living. In most traditional settlements like in the case of Makurdi where culture and government guides and regulates the allocation of land, most of the speculators, pursuing market incomes, do away with the difficulty and over-throwing official regulations affecting the records control and zoning laws and thus paving way for various urban land use problems.

1. It is recommended that future research should carry out classification of the whole Benue State.
2. The Landuse pattern in Makurdi town should be improved upon for preservation of ecosystem.
3. The all concerned environmental scientists should encourage the development of greenery in Makurdi town to improve cross ventilation to avert excessive heat in the town.

VI. REFERENCES


