Biodiversity hot-spot modeling and temporal analysis of Meghalaya using Remote sensing technique

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ABSTRACT

Biodiversity is variation of leaving creatures within an ecosystem, biome or an entire planet. Health of an ecosystem can be measured through this variation. Remote sensing helps to manipulate and analyze the image data produced by these remote sensors. The primary goal of remote sensing is not only the obtain knowledge, but also its application of gained knowledge. Satellites provide real-time global coverage of the Earth. Biophysical spectral modeling techniques allow stratifying vegetation types based on the canopy closure (Roy et al., 1996). Through this such approach mapping and monitoring of forest condition and degradation processes can be done. This study has been taken up Meghalaya, state of India. The flora of Meghalaya is the richest in India. A wide variety of timber species, medicinal plants, and economically important plants are reported from this region. Due to lack of systemic approach it is being destroyed by weed, firewood, timber, jhum cultivation. Large scale over exploration has led to decrease in population of various orchids found here. Here in this study LISS-III data are used.

Keywords: Classification, NDVI, Patchiness, Porosity, Interspersion, Shape index.

1. Introduction

The North Eastern Region (NER) of India combined of the states of Arunachal Pradesh, Assam, Manipur, Nagaland, Mizoram, Sikkim and Tripura. The region stretches between 21⁰ 50’ and 29⁰34’N latitude and 85⁰34’ and 97⁰50’ E longitude. The region has a population of 39 m and geographical area of 26.2 million hectare. On an average, the NE region receives about 2450 mm of rainfall. The Cherrapunji-Mawsynram range receives rainfall as high as 11,500 mm, annually. Great variation in temperature regime can be find too in this region. The temperature varies from 15⁰C to 32⁰C in summer and 0⁰C to 26⁰C in winter. At the confluence of the Indo-Malayan, Indo-Chinese and Indian biogeographical realms, the NE region is unique in providing a profusion of habitats, which features diverse biota with a high level of endemism. The region is also the residence of approximately 225 tribes in India, out of 450 in the country. North eastern region has been in focus for its high biodiversity and this region has been a priority for leading conservation agencies of the world.

At global level many works has done on Biodiversity using Remote sensing and GIS. P.S Roy et al. (1999) worked on Biodiversity Characterization at landscape level using

2. Study area

The study “Modeling on Biodiversity hot-spot modeling and temporal analysis of Meghalaya using Remote sensing technique” has been taken up Meghalaya state of India is a state in north-eastern India. Geographically the area lies between coordinates 25°0’00” N to 26°10’00” N and 89°45’00” E to 92°45’00” E. Area of Meghalaya is about 8,700 sq mi (22,720 km²). The population numbered 2,175,000 in 2000. The state is bounded on the north by Assam and by Bangladesh on the south. The capital is Shillong also known as the Scotland of the East, which has a population of 260,000. It was previously part of Assam, but on 21 January 1972, the districts of Khasi, Garo and Jaintia hills became the new state of Meghalaya. The area is rich in a wide range of flora and fauna. The vegetation is very interesting having a mixture of Asiatic and Indian Peninsular elements. Meghalaya occupies a unique position in the North Eastern Himalayas. More than 90 per cent of the forested areas fall in private or community lands, the richness of biodiversity in these areas outside the state owned lands cannot be regarded as permanent repositories. The chances of them being put under shifting cultivation are inherently predominant (Singh, 2001). This state has two national parks and three wildlife sanctuaries, the national parks covers an area of 267.48 km² approx. These protected areas owned by the state forest department are diverse and support a large number of species, which are important with respect to biodiversity.

![Figure 1: Map showing study area (Meghalaya)](image_url)
3. Objectives of the study

1) Preparation of vegetation cover type and land use maps using temporal satellite remote sensing data to identify Vegetation changes over Meghalaya between 1997 and 2007.

2) Monitoring the biological rich area of Meghalaya. This study is carried out using IRS 1C-LISS III images of Year: 1997 and 2007. ASTER DEM, Forest map of Meghalaya (Forest and Environment Department of Meghalaya), SOI topo-sheets on 1:250,000, Rainfall and Temperature data from Indian Meteorological Department have been used as Ancillary data.

4. Material and methods

This study is carried out using IRS 1C-LISS III images of Year: 1997 and 2007. ASTER DEM, Forest map of Meghalaya (Forest and Environment Department of Meghalaya), SOI topo-sheets on 1:250,000, Rainfall and Temperature data from Indian Meteorological Department have been used as Ancillary data.

Methodology used to carry out this study is divided mainly into two parts i.e. Vegetation / Land Cover Mapping and Monitoring Biological rich areas. The brief descriptions of the methodology along with Flow Charts are given in figure 2 and 3.

4.1 Methodology for Vegetation / Land Cover Map:

Satellite images are geo-rectified from 1:250000 SOI topo-sheets and mosaic together. Mosaic file is further subseted by administrative vector boundary (figure. 1) of Meghalaya. NDVI values are extracted and classified. Then main subseted image have classified by hybrid classification technique and classified NDVI image used as vegetation mask (figure. 4) based on knowledge based approach. Extracted administrative boundaries, communication and settlement layers are superimposed on classified vegetation layers.
Figure 3: Methodology for Monitoring Biological rich areas

The classified vegetation and land cover images are further classified in forest and non-forest areas. Extracted Bio rich areas from satellite images (work done previously by NESAC) have used as mask. After this landscape analysis like patchiness, porosity, and interspersion has done. Patchiness is a measure of the density of patches of all types (Romme, 1982). The vegetation/land cover type map was reclassified into two classes’ viz., forest and non-forest. A grid cell of n x n is convoluted through the entire spatial layer.

\[ P = \frac{D_i}{N} \times 100 \]  

Where \( N \) is the number of boundaries between adjacent cells, and \( D_i \) is dissimilarity value for the \( i^{th} \) boundary between adjacent cells. Count of density or number of patches of patches within single land cover type. Lower porosity values indicate less interaction among the landscape elements and higher porosity values indicate higher interaction among the landscape elements and heterogeneity resulting in high fragmented landscape.

\[ PO = \sum_{i=1}^{k} Cp_i \]  

Where \( Cp_i \) is the number of closed patches of \( i^{th} \) cover class.

Interspersion is the measure of spatial intermixing of land use/land cover. It is calculated by the number of surrounding grid cells that differ from the central cell. It shows the homogeneity of the landscape and landscape diversity. For analyzing interspersion 3X3 grid has been moved over the classified images.

\[ I = \frac{\sum_{i=1}^{k} SF_i}{N} \]  

(Lyon 1983)

Where \( SF_i \) is shape factor.

Calculations of disturbance patches are calculated by shape index value through object base approach. The smoother the border of an image object represents lower its shape index. It is
calculated from the Border Length feature of the image object divided by four times the square root of its area. Smoother shape represents less disturbed patch and irregular shape indicate high disturbed patch.

\[
\frac{b_v}{\sqrt{4F_v}}
\]  

(4)

Where \(b_v\) is the image object border length and \(\sqrt{4F_v}\) is the border of square with area.

**Figure 4:** Derived Vegetation mask

**Figure 5:** Showing the vegetation type of 1997
**Figure 6:** Showing the vegetation type of 2007

**Figure 7:** Fragmentation 1997
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Figure 8: Fragmentation 2007

Figure 9: Homogeneity 1997
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Figure 10: Homogeneity 2007

Figure 11: Porosity 1997
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Figure 12: Porosity 2007

Figure 13: Snowing disturbance patches in 1997
Figure 14: Snowing disturbance patches in 2007

Table 1: shows the changes between 1997 and 2007

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Semievergreen</td>
<td>479250.67</td>
<td>665553.13</td>
<td>186302.46</td>
</tr>
<tr>
<td>Evergreen</td>
<td>312999.18</td>
<td>428611.72</td>
<td>115612.54</td>
</tr>
<tr>
<td>Sal</td>
<td>12899.3</td>
<td>10002.73</td>
<td>-2896.56</td>
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<tr>
<td>Bamboo</td>
<td>13329.82</td>
<td>25661.72</td>
<td>12331.9</td>
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<tr>
<td>Mixed pine</td>
<td>116019.77</td>
<td>104281.25</td>
<td>-11738.52</td>
</tr>
<tr>
<td>Pine</td>
<td>26867.28</td>
<td>52501.56</td>
<td>25634.28</td>
</tr>
<tr>
<td>Degraded forest</td>
<td>136816.31</td>
<td>50974.61</td>
<td>-85841.7</td>
</tr>
<tr>
<td>Agriculture</td>
<td>64532.85</td>
<td>28810.16</td>
<td>-35722.7</td>
</tr>
<tr>
<td>Abandoned Jhum</td>
<td>737562.74</td>
<td>461928.13</td>
<td>-275634.62</td>
</tr>
<tr>
<td>Grassland</td>
<td>329641.81</td>
<td>390532.42</td>
<td>60890.61</td>
</tr>
<tr>
<td>Water body</td>
<td>8696.12</td>
<td>13433.98</td>
<td>4737.87</td>
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Table 2: Fragmentation 1997

<table>
<thead>
<tr>
<th>Category</th>
<th>Area in ha</th>
</tr>
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<tbody>
<tr>
<td>High</td>
<td>5812.25</td>
</tr>
<tr>
<td>Medium</td>
<td>7080.1</td>
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<tr>
<td>Low</td>
<td>5176.47</td>
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</table>

Table 3: Fragmentation 2007

<table>
<thead>
<tr>
<th>Category</th>
<th>Area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>117258.2</td>
</tr>
<tr>
<td>Medium</td>
<td>514193</td>
</tr>
<tr>
<td>Low</td>
<td>757079.7</td>
</tr>
</tbody>
</table>

Table 4: Homogeneity 1997

<table>
<thead>
<tr>
<th>Category</th>
<th>Area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>557112.1</td>
</tr>
<tr>
<td>High</td>
<td>516328.5</td>
</tr>
</tbody>
</table>

Table 5: Homogeneity 2007

<table>
<thead>
<tr>
<th>Category</th>
<th>Area in ha</th>
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</thead>
<tbody>
<tr>
<td>Very high</td>
<td>664682.2</td>
</tr>
<tr>
<td>High</td>
<td>617746.8</td>
</tr>
</tbody>
</table>
Forests of Meghalaya have been classified into Sub-Tropical-Evengreen, Semi-evergreen, Grasslands, Sal forest, Bamboo forest, Mixed pine forest, Pine forest, Degraded forest, Agriculture, Abandoned Jhum, Water body. From the comparative study between 1997 and 2007 (figure.5 and 6) it is found that 325246 ha forest areas are reduced within ten years. In the other hand Jhum cultivation is increased about 275634 ha. Following table no.1 is shown the changes.

The parameters like fragmentation, porosity, and interspersion have been used to understand the disturbance regime and biologically rich areas. Forest fragmentation is one of the greatest threats to biodiversity in forests, especially in the tropics. The effect of fragmentation on the flora and fauna of a forest patch depends on a) the size of the patch, and b) its degree of isolation. From the compare study between 1997 and 2007 (figure. 7 and 8) it can be seen that total fragmentation is highly increased (table 2 and 3). Forests under the private land parcels are fragmented more. Re bhoi, East khasi hills, jaintia hills are more affected by forest fragmentation. Human land uses, like shifting cultivation, tend to expand over time in this area.

Interspersion represents the spatial intermixing or homogeneity (Figure 9 and 10) among the landscape features. Higher value of interspersion means dispersal ability of the central class will be low or reduced or in other words the influence of resistance by neighbors will be much which may lead to the extinction of the central class.

Porosity shows the overall clue of to the change of species isolation between 1997 and 2007. In the maps (figure 11 and figure 12) Lower porosity value indicates the lower interaction among landscape elements, homogeneity and low fragmented habitats in the forest class and higher porosity value indicates the higher interaction among landscape elements, heterogeneous and high fragmented habitats in the forest class. During ten years period the porosity is increased in the state (table 6 and 7).

<table>
<thead>
<tr>
<th>Category</th>
<th>Area in ha</th>
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</thead>
<tbody>
<tr>
<td>High</td>
<td>360139.8</td>
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<tr>
<td>Medium</td>
<td>235832</td>
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<tr>
<td>Low</td>
<td>354931.3</td>
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Table 6: Porosity 1997

<table>
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<th>Area in ha</th>
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<tr>
<td>High</td>
<td>441422</td>
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<tr>
<td>Medium</td>
<td>298583.1</td>
</tr>
<tr>
<td>Low</td>
<td>854694.9</td>
</tr>
</tbody>
</table>

Table 7: Porosity 2007

5. Result and conclusion

5.1 Forests of Meghalaya have been classified into Sub-Tropical-Evengreen, Semi-evergreen, Grasslands, Sal forest, Bamboo forest, Mixed pine forest, Pine forest, Degraded forest, Agriculture, Abandoned Jhum, Water body. From the comparative study between 1997 and 2007 (figure.5 and 6) it is found that 325246 ha forest areas are reduced within ten years. In the other hand Jhum cultivation is increased about 275634 ha. Following table no.1 is shown the changes.

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It is previously mentioned that category of disturbance patches in biorich area is calculated by shape index value. These parameters were derived using detailed object based analysis. The disturbance type has been derived using masking and classification technique. For the better analysis patch categories are divided into highly disturbed, very highly disturbed, less disturbed, very less disturbed. Very highly disturbed area represents man made features, highly disturbed area represents Jhum cultivation and agricultural areas, less disturbed area represents natural vegetation cover changes, and very less disturbed area represents degraded forest, grassland etc (Figure 13 and 14). Bellow table 8 shows the changes between 1997 and 2007.

From the above study it is clearly seen that Biodiversity of Meghalaya is under great threat due to impact of human activities. Old practice of shifting cultivation, over exploitation of forests and mining activities are responsible for loss of biodiversity. Permanent agriculture in the higher plateaus has also resulted in the loss of forest cover. From the study of this project it is found that in 1997 there were 57.47% forest cover in Meghalaya but in after ten years, in 2007 forest cover reduced at 42.92%. It is clearly seen that the jhum cultivation is increased about 12% during ten years. It is also observed that fragmentation of landscape has been one of the major causes of biodiversity loss. Disturbance patch in biorich area in 1997 was 368.56 km² and in 2007 it increased almost double at 674.72 km² which affects the Biologically rich areas of Meghalaya. The species like Diospyros undulata, Nymphaea pygmaea and Luvunga scandens are thought to be locally extinct (Khan et al., 1997). Important bio-rich sites identified in Meghalaya are Nokrek Biosphere reserve and Balphakram National Park. So it is recommended that immediate action must be taken to control human impact on forest resources especially in biorich areas.

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6. References


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