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ABSTRACT

This research work has been carried out to assess the impact and effectiveness of watershed management practices on land use land cover of the Seoni watershed area with the help of satellite remote sensing and Geographic information system. Simultaneously the prediction (2021) of land use land cover conversion has also been done for the agriculture, forest, scrub and other classes (Including water bodies, fellow land, non-forest and settlement) using Cellular Automata Markove (CA-Markove) model. Landsat TM data of the year 1990, 2000 and 2011 has been used for the study of land use land cover changes. Semi-automatic unsupervised iterative self-organized data (unsupervised ISODATA) algorithm has been used to classify the satellite data. Forest, agricultural land, Water and non-forest were the broad land use/cover classes have been identified in the study area. Drastic change in the forest and agricultural area with a decrease in forest by 2541 ha. and increase in the agricultural area by 2854ha. has been obtained since 1990 to 2011. This change analysis itself is showing impact and effectiveness of the watershed management practices over forest and agriculture respectively. Predictive modeling of the land use/cover conversion is showing similar results as obtained by the satellite data observations. Increase in the agricultural area by about 6.00% and decrease in the forest area by about 4.1% has been modeled via CA-Markove model. Model generation was based on the four land use/cover classes i.e. forest, net shown area (agriculture), scrub and other classes (including water bodies, fellow land, non-forest and settlement). Broad vegetation indices (SBI & NDVI) has been calculated and used for analyzing changes in forest, agriculture and soil condition. The hypothesis was that the soil brightness will decrease as an effect of soil moisture increase due to watershed management practices and same has been obtained during the year 1990 to 2000 but after this 10 consecutive drought year has disturbed the trend and the increased soil brightness frequency has been obtained during the year 2000 to 2011. NDVI analysis is showing improved vegetation condition and agriculture which would be the result of ground water recharge due to improved water harvesting as a result of watershed management practices although the rainfall was less.

Keywords: Impact and effectiveness, Broad band vegetation Indices, CA-Markove model, Watershed, Unsupervised ISODATA.

1 Introduction

1.1 Background
The watershed development is mainly a land based management programme, which is increasingly being focused on water and soil conservation. The main objective is to enhance agricultural productivity by increasing in situ moisture conservation and protective irrigation for socio economic development of rural people (Joshi, et al. 2004, 2006). Taking this in view the country wide watershed development projects sectioned by the government of India during 1995-1998, and had been taken up by ministry of rural development. Another country wide watershed development project had been sectioned during the 1998-2002 and National Institute of rural development was the nodal agency (Dr. Prem Singh et.al. 2010). The results of the watershed development projects have been analyzed by the organizations like National institute of Rural Development (NIRD), State Institute Rural Development (SIRD), Gujarat Institute of Development Research (GIDR), People's Science Institute (PSI) Dehradun; Watershed Support Services and Activities Network (WASSAN), Skill-Pro Foundation and Madras Institute of Development Studies (MIDS) using ground survey and geospatial approach. The benefits have been seen in the forms of, enhanced quality of the water harvesting structures, reduction in the soil erosion, increase in the surface and ground water level, change in the land use land cover pattern, cropping intensification and reduced work burden (Dr. Prem Singh et al., 2010). Although these benefits are seems to be valuable for the society it may not necessarily virtuous for the environment. Thus analyzing both prose and cones of project activities are of prime importance.

Impact assessment of the watershed management practices on the land use and land cover classes using geospatial technology could be effective in the verification of the real situation on ground and to assess the effectiveness of governmental policies regarding watershed management. The watershed management practices helps in the conservation of rain water and flood control simultaneously it impacts the agricultural production, agricultural extent, and other land use land cover classes both positively as well as negatively which cause changes in land features. Information’s gathered from Satellite remote sensing in cost effective manner, and their integration in geographic information system (GIS), has been extensively applied and been accepted as an effective and powerful tool for identifying, detecting and predicting land use and land cover change (Brown et al., 2004.; Weng, 2002). There are many methods for the change detection such as Image differencing, Image Indexing, Change vector analysis etc. Over the last few decades, several researchers have improved measurements of land cover changes, the understanding of the causes of land use change, and predictive models of land use land cover change under the land use land cover change project of the International Geosphere Biosphere programme (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP) (Lambin et.al., 2003).

As watershed areas are vulnerable in term of soil erosion due to surface run off it is primary requirement to conserve soil as well as water in these areas with the use of modern management practices. Simultaneously we must have a précised and cost effect method to collect information about the real situation on ground regarding impact and effectiveness of these management practices. In this context remote sensing and simulation models have been applied by researchers and watershed managers to analyze the impact that different watershed management practices may have on land use land over of the watershed area and hydrological regime of the catchment (Mansour D. Leh, 2009). The present study has been taken to (a) asses the changes in the land use land cover since 1990 to 2011 in the watershed area and (b) prediction of the changes in forest cover may take place in the next decades using cellular automata Markove model. Integrated potential of remote sensing, GIS, modeling techniques and spatial statistics have been applied to obtain the desired outputs.
1.2 Why Markove modeling for change prediction?

The first review related to land cover change was published by Baker (1989). Baker categories the change models according to the need of detailed information integrated in the model. The whole landscape model seeks to simulate changes in aggregate attribute or state of the landscape over time say as forest and non forest in a landscape. The widely applied Distributional models used till date which exclude spatial detail and describe changes in the proportion of the landscape in different land cover classes, say as change of open forest class to medium dense forest class. However the spatial model requires spatial detail and describes location and configuration of changes in land cover (Baker, 1989; Brown, 2004). But Baker (1989) model were focused towards landscape ecological processes that did not show the real representation of changes due to human decision making. Later on Agrawal et al. (2002) describes 19 models. These were depends on dimensions of space, time and human decision making. The findings of the survey of nineteen models by Agrawal et al. (2002) had revealed that the Markove model have strength to consider both temporal changes and spatial changes of land features may or may not due to anthropogenic activities. As our study area is influenced by all the three factors i. e. dimensions of space, time and human decision making we require a model that can reflect all these factors. Fortunately Markove model in combination with the Cellular Automata (CA-markove model) provides us opportunity to predict changes considering all these factors. The cellular automata model so far has been extensively used in the urban area modeling (Agrawal et al., 2002) but the forest change prediction in the watershed area is less explored till date.

1.3 Markove modeling of land use land covers change prediction

Land use and land cover change (LUCC) is a major issue of global environmental problems. Both social and scientific research community called for substantive study of land use changes at the Stockholm Conference on the Human Environment (1972), and again 20 years later, at the United Nations Conference on Environment and Development (UNCED) in 1992. Different worker have worked for the identification, prediction and simulation of the land use land cover change (Kushwaha, 1990; Weng, 2002; Walter, 2004; Prakasam, 2010; Singh, 2011).

The modeling to forecast the future scenario could be used to evaluate land use system and to manage the ecological structure. Predictive models could also be useful in the management of natural resources, and the climate change prediction. In the present study we have taken the three dimensions of the change process i.e. time, space and the anthropogenic activity. Cellular automata Markove model is used to integrate all these three dimension of the land use land cover change. Till data it has been used to model changes in land use and land cover at a variety of spatial scales from small area of less than few hectares to thousands of hectares or much larger spatial scale (Bell, 1974; Bell and Hinojosa, 1977; Baker, 1989; Muller and Middleton, 1994; Weng, 2002).

Markove model works as stochastic process that means a process in which the value Xₜ depends only on its Value, Xₜ₋₁ at time t₋₁(simple random walk).This is not dependent on the sequence of values Xₜ₋₂, Xₜ₋₃, Xₜ₋₄, ...... , X₀. It can be represented as

\[ P[Xₜ=a₉|X₀=a₀, X₁=a₁, \ldots, Xₜ₋₁=aₐ] \]
\[ =P[Xₜ=a₉|Xₜ₋₁=aₐ] \]

This is convenient in the context of change processes in discrete time (t= 0,1,2,3,4,……….).
If a process shows transition from state $a_i$ to $a_j$ in one time period it is known as one-step transition and its probability is known as one step transition probability. It is represented as

$$P \{ X_t=a_j | X_{t-1}=a_i \}$$

Similarly if ‘n’ steps are needed to put into operation for this transition, it is called as the ‘n’-step transition probability, $P_{ij}^{(n)}$. It is represented as

$$P \{ X_t=a_j | X_{t-1}=a_i \}$$

If n-step transition probability is dependent only on the states $a_i$, $a_j$ and no. of steps but independent of time it is known as homogeneous Markov chain process. Weng (2002) study on Markov chain model for land use land cover change was limited to first order and homogeneous Markov chain i.e. probability of a state depends only on the probability of the previous state. In this situation the transition probability would be

$$P[X_t=a_j | X_{t-1}=a_i] = P_{ij}$$

(Where $n_{ij} = n_{ij}/n_i$)

$n_{ij}$ is the no of times, the observed data went into the j state from i state and $n_i$ is the total no of time, the $a_i$ occurred.

This model provides us the transition probability of transformation of one land use land cover class into the other class. Data used in the Markov modeling could be obtained from field survey, arial photograph or satellite remote sensing. Previous studies mostly utilize data derived from field surveys, existing maps, or aerial photograph (Drewett, 1969;; Bell and Hinojosa, 1977; Robinson, 1978; Jahan, 1986; Muller and Middleton, 1994). Brown et al. (2000) worked on similar approach to estimate transition probabilities between two thematic images of binary nature acquired by satellite remote sensing for the modeling of land use and land cover relationship in the Upper Midwest, USA. Different Statistical methods including CA Markove were used for the prediction of Deforestation in the part of Chhattisgarh District by Kumar, et al. (2011). Recently CA Markov modeling has been used by Maorya et al. (2013) for the change prediction of the forest cover in the part of Himanchal Pradesh.

2 Materials and methods

2.1 Study area

Seoni district is situated in the southern part of the Madhya Pradesh state (geographical extent 21° 35’ - 22° 58’ N and 79° 12’ - 81° 18’ E) and covers area over 8,752 sq. km. Tribal communities, contribute about 90% of the total population. The geology of the district comprises of Tirdodi Biotite Gneiss (TBG), Mica Schist of Supracrustal Sausar Group - (SSG), Quartzite, Muscovite-Biotite schist of Mansaur series, Calc Silicate rocks of Lohangi series, Quartzite, Quartz-Muscovite schist of Charbaoli series and Crystalline Limestone and Dolomite of Bichua series in the southeastern parts, whereas, remaining part of the district was covered by Deccan Traps with sporadic occurrence of lameta, intertrappean beds, laterite cappings and Meso-Proterozoic to recent alluvium (Bobade et.al., 2010). Climate of the area is tropical monsoon type. The mean annual rainfall (MAR) recorded was 1385 mm and average rainfall 1170mm. June and September month receives highest rainfall in the study area (85%). The main agricultural crops are Paddy, Kodokutki, Soybean, Wheat and Gram covering an area of 379100 ha. for whole district. Presently taken watershed area is the part
of Seoni district come under the Seoni watershed region and covering an area of about 345.45 sq. km. The geographical Extent of the Seoni Watershed is 22 46 03.42 N to 81 23 07.24 E and 22 26 22.78 N to 81 39 24.55 E. State Level Rajiv Gandhi Mission for Watershed Management (RGMWM) has been implemented in August, 1994. It is also identified as National Agricultural Research Project (NARP) zone.

Figure 1: Spatial Location of the Study area

2.2 Methodology

2.2.1 Image Processing and Broad band Indices extraction

The Landsat images of the year 1990, 2000 and 2011 were downloaded from earth explorer. The images were corrected geometrically using the SOI toposheet of 1:50000 scales as the reference using ERDAS imagine satellite data processing software. Further image processing was done as radiometric normalization of all the images. Simultaneously the ASTER Digital elevation model was downloaded to extract slope, aspect, drainage and watershed area. Hybrid (semi-automatic unsupervised algorithm followed by visual interpretation) approaches of image classification were used to prepare the land use land cover of the study area. The change between 1990 and 2000 were analyzed and a change map was extracted to identify and quantify the impact and effectiveness of the watershed development programme on the land use land cover classes and their change pattern. Soil brightness index (SBI) was extracted of three times i.e. 1990, 2000 and 2011 considering pre-implementation phase,
implementation phase and post implementation phase for the analysis of impact of watershed management practices on the brightness of the soil.

\[ \text{SBI} = \{(0.4233 \times B1) + (0.4328 \times B2) + (0.6490 \times B3) + (0.4607 \times B4)\} \quad \text{(1)} \]

(Velmurungan and Carlos, 2009)

Similarly Normalized difference vegetation index (NDVI) have been extracted for the assessment of amount and condition of the vegetation. Before calculating the indices the satellite data first have been normalized for similar radiometry.

\[ \text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \quad \text{(2)} \]

\[ \text{Change} = \text{Image}T_2 - \text{Image}T_1 \quad \text{(3)} \]

Table 1 is showing detailed area analysis of the deferent LULC and change dynamics. The graph plotted against area of deferent land use land cover for the three time period to visualize the change pattern in the LULC (figure 3).

2.2.3 Assessment and prediction of effectiveness and Impact of watershed management practices
Ground survey related to the agricultural productivity, management practices of watershed, year of management plan implementation etc. were done using questionnaires. Collected data were used for making inferences about the impact and effectiveness of watershed development project. NDVI and SBI were used to assess the change pattern in vegetation and soil brightness in the study area. These were graphed (figure 5 a & b) to visualize the effectiveness and impact. A predictive model for the year 2021 was prepared finally, using the land use land cover maps of the year 2000 and 2011 to predict the future impact. CA-Markov model was used for the predictive modeling in the present study with 5×5 contiguity filter and equal probability of land use/cover conversion. EDIRSI Selva software has been used for developing the predictive model. The whole approach has been summaries in the above flowchart of methodology (figure 2).

3 Result and discussion

3.1 Land use land cover change

The tables 1 is showing continuous increase in the agricultural land which is indicating the linear and positive correlation between the anthropogenic activities and agricultural land increment. The agricultural land which was the 15901 ha in the year of 1990 has been increased to the 17624 ha till 2000 and 18755 ha till 2011. A total of 1723 ha increase in the area of agriculture has been obtained between the years 1990 to 2000. Similarly 1131 ha increase in the area of agricultural land has been obtained during the year of 2000 and 2011. This increment in the area of agricultural land would be due to the increase in population and its needs. Another is Watershed management practices which results into the increase in water both surface as well as ground. At the same time area of the forest has been decreased drastically by 1303 ha and 1238 ha during the 1990 to 2000 and 2000 to 2011 respectively. A total change in the forest cover since 1990 to 2011 has been obtained about 2541 ha. The watershed management practices have significantly increases the area of the water by about 31 ha. area. Another reason behind the increase would be the heavy rainfall during this year in the study area. Significant decrease in the non-forest area (about 448 ha.) has also been obtained during the year of 1990 to 2000 however this has not been increased by the year 2011 with the similar pattern as followed during the year 1990 to 2000. Most of the non-forest area has been converted to the agricultural land which is showing positive impact of the watershed management practices, but the decrease in the area of forest whether it is of low quality, is the negative impact on other hand. The total change in the land use land cover classes since 1990 to 2011 have been obtained as -2541, 2854, 31, -344 for the Forest, Agricultural land, Water and non-forest area respectively.

<table>
<thead>
<tr>
<th>LULC classes</th>
<th>Year (Area ha.)</th>
<th>Change</th>
<th>Total Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>17786</td>
<td>16483</td>
<td>15244</td>
</tr>
<tr>
<td>Agricultural Land</td>
<td>15901</td>
<td>17624</td>
<td>18755</td>
</tr>
<tr>
<td>Water</td>
<td>156</td>
<td>185</td>
<td>188</td>
</tr>
<tr>
<td>Non-Forest</td>
<td>702</td>
<td>254</td>
<td>358</td>
</tr>
<tr>
<td>Total</td>
<td>34545</td>
<td>34545</td>
<td>34545</td>
</tr>
</tbody>
</table>
3.2 Broad band Indices for the assessment of Effectiveness and Impact of Watershed Management Practices

Two broad band indices viz. soil brightness index (SBI) and normalized deference vegetation Index (NDVI) have been derived from the Landsat satellite data for the year of 1990, 2000 and 2011(Figure 4) to assess the impact of the watershed management practices during this time spawn. Respective distribution of NDVI values and SBI values are given in the table 2 and 3. Higher values of NDVI contributing more area of the water shed for the year 1990 representing vegetation richness. For the year 2000 the distribution of NDVI values showing changes. Lower values of the NDVI contributing more area and showing poor health of the vegetation but the value between 0.2 to 0.3 contributing highest area and representing vegetation richness. Negative values of the NDVI increases from 28 ha. to 658 ha. showing increase in the agricultural area in the form of fellow land. This is showing a positive impact of the watershed management practice in the form of crop area intensification. As the time passes the forest condition become healthy but the area of the forest decreased and area of the agriculture increased. This is another indicator of the impact of management practices on the land use land cover dynamics. In the year 2011 the highest values of NDVI were distributed between 0.2 to 0.4 showing mixture of agriculture and forest however the area of most healthy vegetation i.e. NDVI>0.4 has increased showing positive impact of the watershed management. The management practices may leads to the increase in the ground water available for the tree species of the forest which helps in the growth of these vegetation and reflecting in the form of high NDVI values (Table 2).
Figure 4: NDVI and SBI of the water shed are for the year of 1990, 2001 and 2011

Table 2: NDVI value distribution in different value ranges in the term of their area

<table>
<thead>
<tr>
<th>NDVI Values</th>
<th>1990</th>
<th>2000</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Ve</td>
<td>28</td>
<td>658</td>
<td>3</td>
</tr>
<tr>
<td>&gt;0&lt;=0.1</td>
<td>697</td>
<td>5883</td>
<td>28</td>
</tr>
<tr>
<td>&gt;0.1&lt;=0.2</td>
<td>2933</td>
<td>8717</td>
<td>4293</td>
</tr>
<tr>
<td>&gt;0.2&lt;=0.3</td>
<td>6617</td>
<td>11718</td>
<td>12799</td>
</tr>
<tr>
<td>&gt;0.3&lt;=0.4</td>
<td>7355</td>
<td>7456</td>
<td>12357</td>
</tr>
<tr>
<td>&gt;0.4</td>
<td>16915</td>
<td>114</td>
<td>5065</td>
</tr>
</tbody>
</table>
Similar results have been obtained from the Soil brightness Index also. The lower value of this index shows high vegetation and as the frequencies of higher values increases it shows decrease in the forest area and increase in the exposed land. The frequencies and coverage area of higher values for the soil brightness index are showing an increase in the area of agricultural land since 1990 to till date however a little decrease in the soil brightness have been found in the year 2000. The possible reason behind this would be the implementation phase and high water storage. The values above then 90 are considered as bare soil and also verified from the ground survey of limited area. This is highest in the year 2011 showing increase in exposed land due to agricultural practices. Another reason behind the increase in the high value frequency of SBI in 2011 is due to the 10 consecutive droughts (Table 3).

Table 3: SBI value distribution in different value ranges in term of their area

<table>
<thead>
<tr>
<th>SBI Values</th>
<th>1990</th>
<th>2000</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=50</td>
<td>996</td>
<td>4177</td>
<td>0</td>
</tr>
<tr>
<td>50.01-60</td>
<td>13671</td>
<td>17416</td>
<td>386</td>
</tr>
<tr>
<td>60.01-70</td>
<td>12625</td>
<td>9824</td>
<td>8411</td>
</tr>
<tr>
<td>70.01-80</td>
<td>6366</td>
<td>2953</td>
<td>11897</td>
</tr>
<tr>
<td>80.01-90</td>
<td>861</td>
<td>168</td>
<td>9525</td>
</tr>
<tr>
<td>&gt;90.01</td>
<td>25</td>
<td>8</td>
<td>4326</td>
</tr>
<tr>
<td>Total</td>
<td>34545</td>
<td>34545</td>
<td>34545</td>
</tr>
</tbody>
</table>

Figure 5: NDVI frequency distribution (a) and SBI frequency distribution (b) in term of area

4. Prediction of the Impact and effectiveness of watershed management practices

On applying the cellular automata model on the LULC (reclassified i.e. all the classes of forest density into forest and scrub, net shown area in to agriculture and other land use into other classes) of the year 2000 and 2011 a model for 2021 (figure 6) has been developed. It has been observed from the model that the agricultural land would increase by about 6.00%, at the same time forest land will be decreased by 4.1% if all the other conditions remain unchanged. Similarly the other classes (Including water bodies, fellow land and settlement) would be increased by 1.9%. A little change has been observed in the Scrub. Water bodies, fellow land and settlement has been included in the other classes for the simplicity of model functioning. As it is evident that the watershed management practices are beneficial for water and soil conservation it has been obtained from the prediction model that these practices may enhance the agriculture area too which may cause the deforestation.
A comparative chart of the changes (since 1990 to 2021) in forest and agriculture has been given in the figure 7.

5. Conclusions

Drastic increase in the area of the agriculture would possibly due to the increase in the population of the area and increased population needs. Watershed management practices are showing negative impact on the forest cover and effectiveness for the agricultural area. From the findings of the land use land cover, NDVI and SBI it has been inferred that the overall health of the forest has been improved in the year 2011 as comparison to the year 2001. However the forest health was depleting since the year 1990 to 2001. The watershed management practices (implemented during 1994 and 1998-2002) would possibly have increased the underground water which has been utilized by the forest vegetation showing good health in term of high NDVI values. The increased area of the high values of SBI is the reflection of 10 consecutive drought years and increase in the area of agricultural land. We observed that the watershed management practices are quite beneficial from the agricultural point of view while it may harm the forest resources of low value. The proper guideline

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regarding optimum land utilization is needed for the watershed area where the management practices are being implemented. The forest resources must be conserved in term of area leaving their timber values. The satellite imageries of the same month of different years would have better opportunity in assessing the impact and effectiveness of the management practices in the watershed areas. 22.44% increase in the area of agricultural land due to watershed management practices as reported by the state government report (web1) is supporting our finding of agricultural land increase (8.26%) from the satellite observations in the watershed area.

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