Examining Temporal Change and Prediction of Future Land Use Using Geospatial Approach: A Case Study of Talpona River Watershed in Goa, India

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Abstract - **Land-use change leads to environmental change on spatial and temporal scales. For better water resource management, understanding the interaction between land-use changes and local hydrology is crucial. This study analyzed the land-use change over past years and predicted the future one in Talpona river watershed in Goa. Land Change Modeler was used for change analysis between satellite images of 1993, 2014 and 2019 map for validation. The Kappa co-efficient of 0.73 indicated acceptable accuracy. Multi-Layer Perceptron neural network was used for prediction of land-use for 2030 and 2040. Results will aid in modeling future water flows and designing adaptation strategies.**

Key words - Satellite images, land-use, Land Change Modeler, Talpona river watershed, Goa

I. Introduction

Land-use change is a dynamic and multifaceted process that connects natural and human systems. It has direct impacts on soil, water and atmosphere and is thus directly related to many environmental issues of global importance (Turner, 2006). It is one of the foremost drivers of hydrologic processes, influencing the available water resources and flow regimes in a river basin around the world (Gashaw et al., 2018). Assessing impacts of LULC changes on hydrology is the essential for watershed management and ecological restoration. Quantification of the impact due to changes in land use on dynamics of stream flow in river basins has been the area of interest for hydrologists in recent years. In the past 30 years, land use changes associated with rapid urbanization and deforestation has greatly altered a large proportion of regions (Wu et al., 2017).

Analyzing the trend in land-use change, examining the future projections and coming up with solutions to negate the harmful impacts has become a major priority of researchers and policymakers around the world. It is in this context; the objectives of this study was estimate the land-use changes over the time and predict the future scenario for Talpona river watershed in Goa, India.

II. Methodology

Talpona river originates in the dense, mixed jungles of Ravan Dongar in between Nane and Kuske on the Sahyadri Mountains. It rises at Ambeghat and flows in western direction through Canacona taluka of South Goa district. It is located between the latitudes ($14^{0}\ 56^{'}\ 34^{''}$ N and $15^{0}\ 04^{'}\ 04^{''}$N) and longitudes ($74^{0}\ 02^{'}\ 05^{''}$ E and $74^{0}\ 14^{'}\ 26^{''}$E). The river is about 41 km and joins the Arabian sea near Talpona village. Kuske, Nadke and Gaodongrem are the tributaries of the Talpona River (RRC, Goa, 2019).

At Ardodhond village, the discharge or water flow of the river is measured by Water Resources Department (WRD), Government of Goa. Taking this gauging station as an outlet, Talpona river watershed was delineated and used for this study. The Shuttle Radar Topography Mission's (SRTM) Digital Elevation Model (DEM with resolution of 30 m) data and slope was used to delineate the watershed using Soil and Water Assessment Tool (SWAT) model. The location of the watershed is shown in the Figure 1. There are 4 major villages namely Talpona, Gaodongrem, Ardodhond, Khotigao that are located in this watershed. The area of this watershed is around 149.93 km^2.

The satellite images were organized and classified for analysis and understanding. Landsat images are among the widely used satellite remote sensing data and their spectral, spatial and temporal resolution make them useful input for mapping and planning projects (Mishra et al., 2014 and Sadidy et al., 2009).Landsat TM 5 images for 1993 and Landsat 8 images for the years 2014 and 2019 were used in developing the future land-use/cover maps for Talpona river watershed. These images were mostly for the month of April/May. The images were projected to WGS-1984 and UTM Zone - 43 N co-ordinate system. ERDAS Imagine was used to perform land-use/cover classification in multi-temporal approach. Each image was separately classified using the supervised classification maximum likelihood algorithm in ERDAS

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Imagine. Google Earth has been used to verify the images and improve its accuracy. The snap-shot of the methodology that was used is shown in the Figure 2. Based on the NRSA land-use /land cover classification system, level 1 has been used for this study. Five categories of land- use were that were used for classification were agricultural land, built-up or urban area, barren land, forests (dense vegetation, shrubs, and marshes) and water bodies (rivers, ponds, lakes and open mine pits filled with water). The built-up category includes settlements, mining areas, and man-made construction activities such as roads.

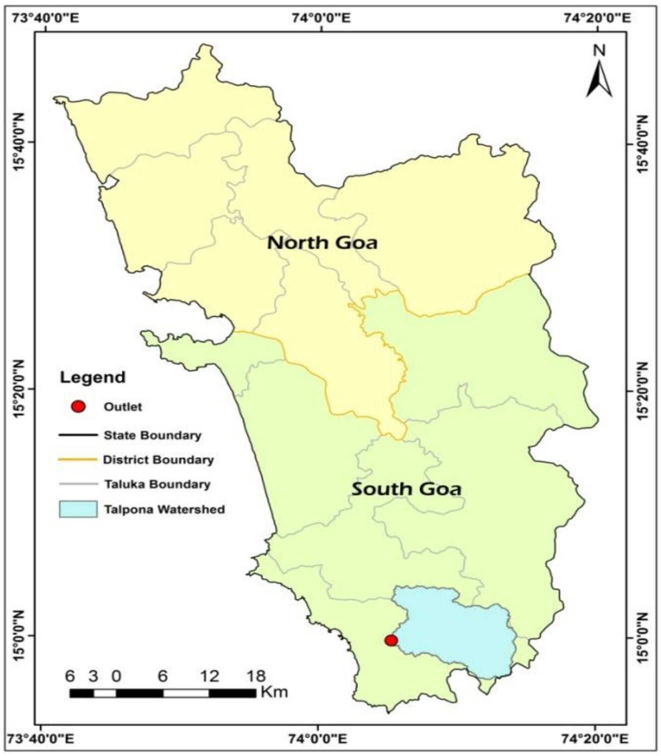

Figure 1: Location of Talpona river watershed at Ardodhond gauging station

The TerrSet Land Change Modeler (LCM) was used to compare and identify the land-use maps generated using the Maximum Likelihood method. Use of such model gives a better understanding of the functions of the land-use systems and the support for planning and policy making. Such models can also predict the possible future change and use of the land cover under different scenario (Anand et al., 2018, Mishra et al., 2014, Ahmed and Ahmed, 2012). The change analysis panel of LCM provides a rapid assessment of quantitative change by graphing gains and losses by land cover categories. A second option, net change, shows the result of taking the earlier land cover areas, adding the gains and then subtracting the losses. The third option is to examine the contribution of changes experienced by single land cover (Clark Labs, 2009). The change analysis between 1993 and 2014 were computed and studied using LCM. Accordingly the transitions and exchanges that took place between the various land-use/cover categories during the years were obtained in a graphical form. All the land cover categories were used in sq. km unit. The transition sub-model maps such as DEM, Slope and VTU were used for predict future land-use in 2019. This map was validated with the current land-use map of 2019. The validation was statistically tested using Kappa co-efficient. Further, future maps for 2030 and 2040 were generated. The methodology of LCM is shown in Figure 3.

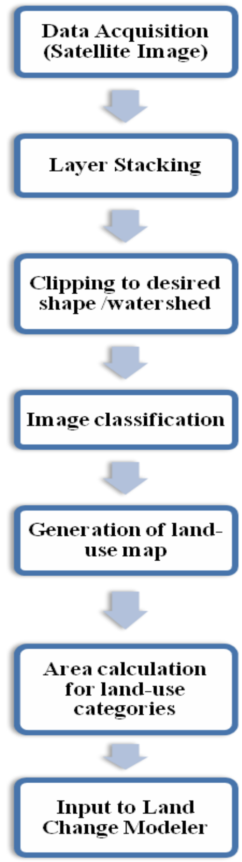

Figure 2: Step-wise methodology that was adopted

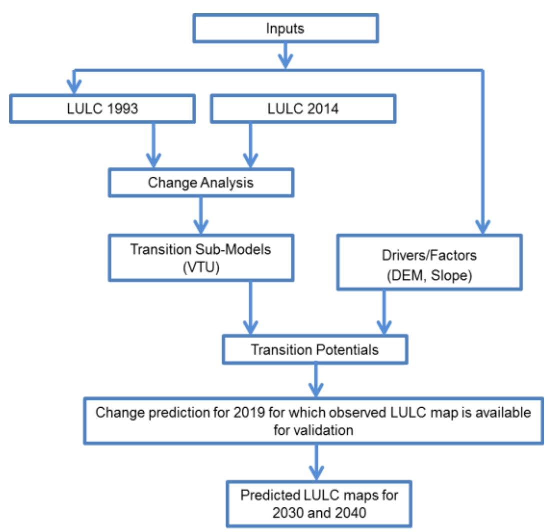

Figure 3: Schematic diagram of the methodology used in LCM

III. Result And Discussion

The 1993 and 2014 land-use layers acted as an observed data for calibration of LCM, while the 2019 classified land-use layer has been used to verify the simulated map for 2019.

Change Analysis**:** From both the classified images of 1993 and 2014, the area of each land-use categories was computed (Table 1; Figure 4) and compared to check whether there were any differences. The LCM module is based on neural network and achievement of higher accuracy is desirable, yet accuracy is highly dependent on influencing factors. The changes in land use have been evaluated by gains and losses amid different classes (Figure 5). Since, Talpona river watershed is close to Western Ghats, forests was the dominant land-use category. From Table 1 and Figure 5, it is clear that there were significant changes and transitions basically among agriculture, forest and barren categories. In 21 years there was decrease in the barren area (-12.75%) whereas all other categories witnessed an increase. The barren lands were reclaimed by the forests in the watershed area, although some of the forest areas near the settlements were converted into agricultural lands (0.13% increase) or built-up land (9%). In case of water a minor decrease (-0.2%) was seen. It was observed that sometimes, the narrow rivers/water bodies get covered with natural vegetation. This creates an obstruction and the water bodies are not detected by the satellite images. This may affect the accuracy of the results a little bit.

TABLE 1
Land-use Classification Statistics between 1993 and 2014

Category	Year 1993 Area (sq.km)	Year 2014 Area (sq.km)	Changed Area (sq.km)	Changed Area (%)
Agriculture	7.97	7.98	0.01	0.13
Forest	132.94	133.71	0.77	0.58
Urban/Settlement	0.83	0.91	0.07	9.00
Barren	6.68	5.83	-0.85	-12.75
Water	1.35	1.35	0.0	-0.2

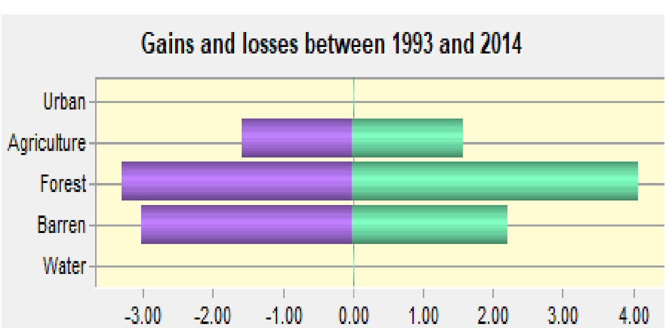

Figure 5: Gains and losses of land-use categories for Talpona river watershed between 1993 and 2014

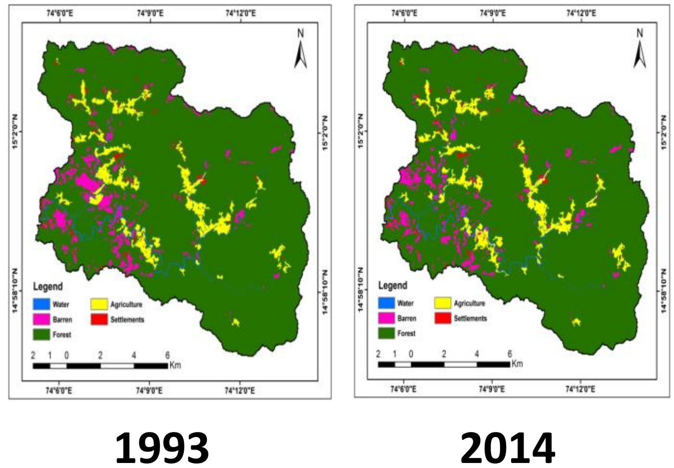

Figure 4: Land-use map of Talpona river watershed for 1993 and 2014

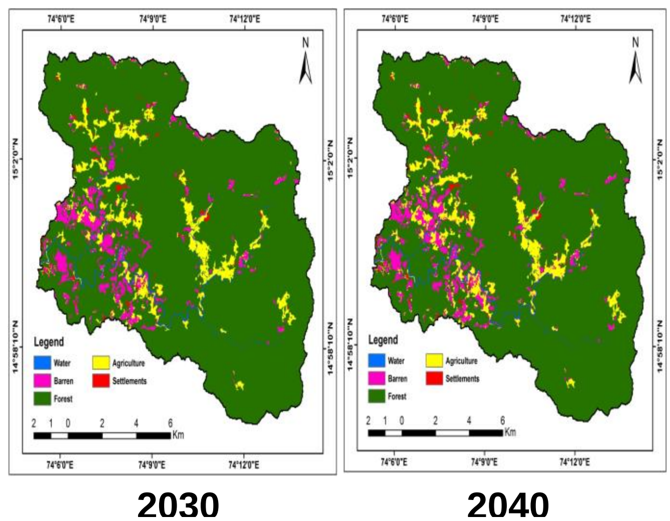

Figure 6: Land-use map of Talpona river watershed for 2030 and 2040

Transition sub-model and prediction model**:** As described in the methodology earlier (Figure 3), transition potential has to be generated in LCM to run the actual prediction model. The transition tab allows to group transitions into a set of sub-models. Further, drivers or variables can be added to the model as static or dynamic components (Eastman, 2006). For the present study LCM in IDRISI Selva has been employed and the flow chart in the Fig. 3 portrays the methodology applied.

In this study, 4 transition sub-models were used which included: (i) Barren to Agriculture; (ii) Forest to barren; (iii) Forest to agriculture; (iv) Agriculture to Barren. DEM and Slope maps were used as variables/drivers. Amongst the modeling algorithms, Multi-layer Perceptron (MLP) neural network was selected since it uses minimal parameters and has been extensively enhanced to offer an automatic mode that requires no user intervention.

Future Prediction: Markov Chain modeling process was used for prediction of future land-use. The procedure determines exactly how much land would be expected to transition from later date to the predicted date based on a projection of the transition potentials into the future and creates a transition probabilities file.

An evaluation of resemblance between the simulated map for 2019 and actual 2019 land-use map was done to examine the applicability of the employed model to successfully envisage the change in distribution of land-use. This has been achieved by employing the 'Validate' module present in the IDRISI. Kappa statistics (K) for similarity was estimated to understand the similarity between the projected and observed land-use maps for 2019 (Anand et al., 2018, Gumindoga et al., 2014). Since the Kappa Coefficient of 0.73 was obtained and which is above 0.7 (Gumindoga et al., 2014, Subedi et al., 2013), the LCM applied for the projection of change in land-use in Talpona river watershed was considered as acceptable. Using this calibrated model, future land-use maps for the years 2030 and 2040 were predicted and are presented in Figures 6. The area under different land-use categories for the years 1993, 2014, 2030 and 2040 is shown in Figure 7. From the graph, it is seen that the area under forests is likely to decrease with an increase in barren and agriculture area. Similar trend in Canacona taluka has been reported by Yedage et al. (2015).

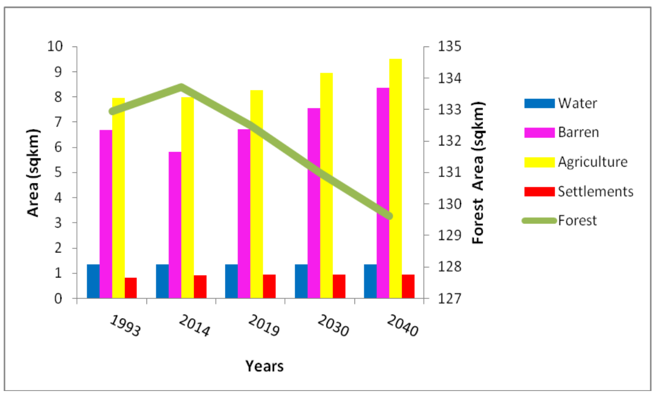

Figure 7: Temporal variation in the area under various land-use categories

IV. Conclusion

The effect of land-cover change resulting from various land-use activities such as deforestation and urbanization is evident in Talpona river watershed. The future land-use scenarios predicted using LCM was found to be statistically acceptable. These results will aid in simulating future water flows and designing/planning adaptation strategies.

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