Visualization of Landscape Dynamics in National Parks of Central Western Ghats

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***Abstract*— National parks and protected areas play a vital role in ecosystem conservation and refuge for sensitive wild flora and fauna, while maintaining ecosystem balance. The human induced land use land cover (LULC) changes are adversely impacting these regions and resulting in the decline of ecosystem goods and biodiversity. The understanding of landscape dynamics in national parks and protected areas is crucial for government, planners, resource managers, and environmental protection agencies to conserve the valuable resources and for maintaining environmental integrity. LULC dynamics in the ecological sensitive regions such as national parks and wildlife sanctuaries of Central Western Ghats were evaluated to assess the role of protection in conservation of biodiversity using spatio temporal remote sensing data with 10 km buffer. The impacts of LULC change in buffer zones surrounding protected ecological reserves have important implications for the management and conservation. The temporal land use analyses reveal ADTR region has lost evergreen forest cover from 84.43 to 50.51% with the increase in anthropogenic activities. CA models are deterministic, stochastic or hybrid approach supporting wide application domains as compared with conventional mathematical tools of spatial simulation. Prediction of forest cover in 2025 is done through Markov-cellular automata (CA–Markov) helps in for inferring intensity, extent and also evolving appropriate forest management strategies of protected areas. The visualization can be aided in planning by enhancing transparency in the administration for sustainable management of natural resources and conservation of ecosystem.**

***Keywords*— Land use Land cover, CA-Markov, Protected areas; National Parks; Central Western Ghats**

INTRODUCTION

The landscapes have its own uniqueness of supporting and maintaining prime natural resources. Land use and land cover are prime components in understanding of land scape, environment and the interactions of the human activities. Land cover is defined as biophysical features present on earth surface such as vegetation (forest, cropland, grass cover, wetland pastures, etc.) and non-vegetation (rocks, open spaces etc.). Land use is defined as the human activities towards the usage of land such as agriculture, urban development, etc. The Earth surface is being altered drastically due to anthropogenic activities affecting to natural ecosystems, such as terrestrial and aquatic ecosystems (Newbold et al, 2015; Ramachandra et al., 2016a; Cuo, 2016). LULC change has been recognized as prime driver of global change in biodiversity. LULC change is governed by demographic, institutional, political, socio-cultural, developmental or environmental factors, influences productivity of the land and biological diversity in protected areas (Geist, 2002). LULC changes in ecologically fragile regions can result in the loss of biodiversity homogenization of vegetation (Kintz et al., 2006), susceptibility to habitat fragmentation, increased edge effects (Harper et al., 2005; Ramachandra et al., 2016b), or an increase in the degree of human activity such as hunting, logging, grazing, or agriculture. Agricultural intensification through adopting economically important crops or land use has triggered tropical deforestation was positively correlated with population growth and exports of agricultural products (DeFries et al., 2010).

Land use change is driven by multiple, interacting factors that originate from the local to the global scales, involve feedback loops, and cascades through land use systems. Understanding LULC changes aid in analyzing regional landscape configuration and composition influenced by plant species composition, nutrient cycling, water flows, and climate associated changes in ecosystem functions (Bharath et al., 2013; Ramachandra et al., 2016b). The regulatory bodies have proposed different levels of land use restrictions to protect or conserve nature and its services by legal status as protected landscapes/areas across the globe (Aukland et al., 2003). Protected areas are created to arrest deforestation, reducing human pressure on biodiversity, eradicating economic exploitation of resources. The protected areas, national parks, wild life sanctuaries have been expanded globally in order to conserve biological and cultural resources of ecosystem from further degradation (Zimmerer et al., 2004). On other hand, there has been accelerated deforestation in surroundings by increasing the density of agents attracted by economic opportunities around parks (Wittemyer et al., 2008). LULC change surrounding a reserve can reduce its conservation capacity, and loss of biodiversity inside a protected area may be attributed to the size or isolation of the reserve (DeFries et al., 2005). Wildlife conservation cannot be restricted to national parks and sanctuaries. Areas outside the protected area network are often vital ecological corridor links and must be protected to prevent isolation of fragments of biodiversity. Buffer zones with controlled land use activities have been suggested as a management strategy to reduce the influence of surrounding land use on biodiversity within the protected area (Byers, 2000; Lynagh and Urich 2002).

The advancement of technologies in vegetation mapping has providing a precise evaluation of the spread and health of forest and accurate up to date land cover change information, environmental consequences. Satellite data has been providing immense help in monitoring LULC change because of the repetitive coverage at short intervals. Remote Sensing (RS) with its advantages of spectral, spatial and temporal nature of data and Geographical Information System (GIS) techniques can be used to provide an updated map of geospatial features in the form of LULC changes of even inaccessible areas within a short span of time. RS technique has proven to be a cost effective tool that provides synoptic coverage of areas of interest and facilitates to quantify LULC change, strong environmental impacts. Modeling and visualization is considered as a conceptual, mathematical approach of deriving relationship between the driving forces such as socioeconomic, political, technological, natural and cultural factors (Verburg et al., 2004; Batty and Torrens, 2005; Ramachandra et al., 2014) of a complex system and their interactions on landscape. Modeling LULC change information at temporal scale helps the decision makers, planers to enumerate the influence of human action on land surface conditions, ecosystem processes and effective management of natural resources. Cellular automata (CA), Markov chain models, agent based models and fractals approaches has evolved as a promising tools of understanding macro to micro level changes and comprehensive projection of a region (Matthews et al., 2007; Bharath et al., 2014). CA models are relatively simple as compared with traditional mathematical models yet produce meaningful results to support decision making in a planning context. CA combined with Markovian process can supports to derive changes based on deterministic logical transition rules accounting the interaction between the various land use and dynamic systems of landscape (Caruso et al., 2005; Bharath et al., 2016). Mondal et al., 2016 highlights the efficiency of CA_Markov LULC model in prediction and validated using statistical test of independence (K^2) was performed; the Markovian suitability has been checked using hypothesis of goodness of fit (Xc^2). The assessments have proved CA Markov model's ability to specify grid cell level location of future change as nearly perfect.

Objective of the study is to analyze

(i) current status and trends in temporal LULC patterns of forest cover in and around protected areas of Central Western Ghats from 1973 to 2016,
(ii) understanding agents of changes for land use dynamics,
(iii) simulation of likely land use in 2026 based on CA-MARKOV analysis.

STUDY AREA

Karnataka state has 43,35,694 Ha forest cover under reserved forest (29,55,022.37 Ha) protected forest (3,58,521.03 Ha), deemed forest (10,11,839.82 Ha) and other minor forest cover. Karnataka state has 5 National Parks, 27 Wildlife

Sanctuaries and 8 Conservation and Community Reserves to protect the environment and wildlife. ADTR (Anshi Dandeli Tiger Reserve) wild life division is formed by Dandeli Wild Life Sanctuary and Anashi National Park notified under section of wild life protection act (WPA), 1972 as (amended upto 2003) with an area of 136774.17 ha. The region has lush green cover and harbours diverse flora and fauna. Sharavathi Wildlife Sanctuary (SWLS) is located in the Sharavathi river basin dominated by dense evergreen to semi evergreen forests in the hills and moist deciduous in foot hills. It was declared as protected wild life sanctuary under section 18 of WPA, 1972 as (amended upto 2003). It is a rich habitat for many exotic species of animals including the lion-tail Macaque, varied mammals, birds and tigers with regular river flow. Mookambika Wildlife Sanctuary is located in Udupi district of Karnataka, named after the goddess Mookambika. The sanctuary was established with AFD.48.FWL.74, dated: 22-05-1978. The lion-tailed macaque and cane turtle found in dense evergreen to semi evergreen forests and rivers Chakra and Sowparnika drain the sanctuary.

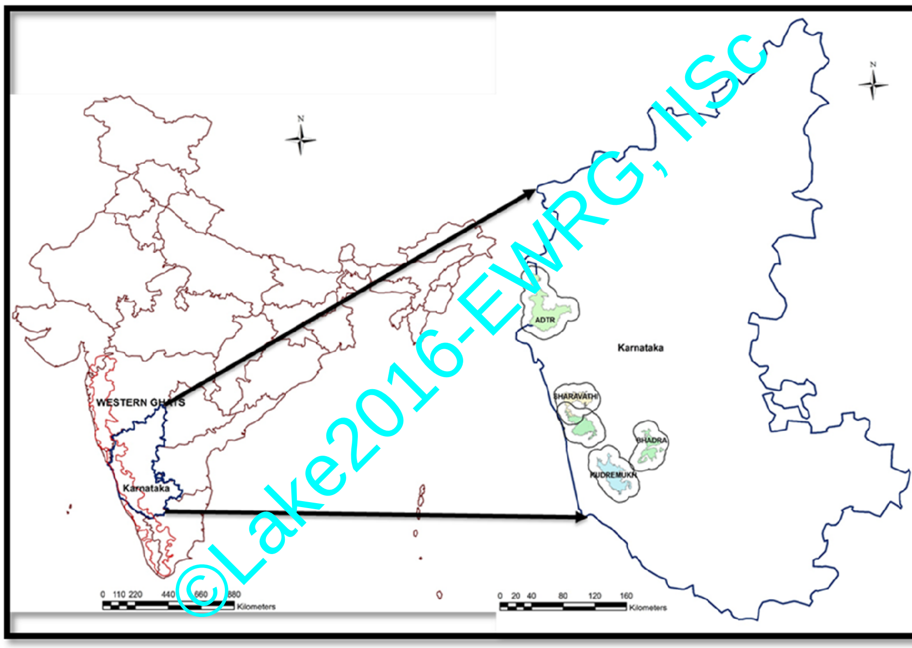

Figure 1: Protected areas selected for the study.

METHOD

LULC changes in selected protected areas of Central Western Ghats and their buffer region (10km) has been analyzed with the help of temporal remote sensing data (RS), ancillary data (collateral data compiled from government agencies) and field investigations (Figure 2). Multi resolution RS data has been acquired through the sensors of U.S. Geological Survey Earth Observation Satellites (EOS), Indian remote sensing system (IRS) at temporal scale. Figure 2 outlines the method followed in the analysis. The RS data used in the study are Landsat MSS (1973), TM (1992), IRS p6L4X (2016) and online Google Earth data (http://earth.google.com) (Table 1). The ancillary data is used to assist the interpretation of different land use types from remote sensing data. Topographic maps provided ground control points to rectify remotely sensed data and scanned paper maps (topographic maps). Survey of India (SOI) topo sheets (1:50000 and 1:250000 scales) and vegetation map of South India developed by French Institute (1986) of scale 1:250000 was digitized to identify various forest cover types and for temporal analyses to find out the changes in vegetation. Pre-calibrated GPS (Global Positioning System - Garmin GPS unit) for field measurements. Ground control points are used to geometrically correct remote sensing data and verify the classified land use information. Land cover analysis has been carried out using NDVI (Normalized Difference Vegetation Index), given in equation 1. NDVI also known as a greenness index, value ranges between -1 to +1. NDVI is sensitive to the presence, density and condition of vegetation and is correlated with absorbed photosynthetically active radiation (PAR) and vegetation primary production. Based on grey scale corresponds to a pixel digital number dense green vegetation and non-vegetation features were separated.

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{R}) \Big/ (\mathrm{NIR} + \mathrm{R}) \qquad \ldots (1)$$

Land use analyses involved (i) generation of False Color Composite (FCC) of remote sensing data (bands–green, red and NIR). This composite image helps in locating heterogeneous patches in the landscape, (ii) selection of training polygons by covering 15% of the study area (polygons are uniformly distributed over the entire study area) (iii) loading these training polygons co-ordinates into pre-calibrated GPS, (vi) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, (iv) supplementing this information with Google Earth and (v) 60% of the training data has been used for classification, while the balance is used for accuracy assessment. The land use analysis was done using supervised classification technique based on Gaussian maximum likelihood (GML) algorithm with training data (collected from field using GPS). GRASS GIS (Geographical Resources Analysis Support System, http://ces.iisc.ernet.in/grass), a free and open source software with the robust support for processing both vector and raster data. The land use analysis has provided spatial pattern and Markovian process is used to generate transition probability map and area matrix, obtained based on probability distribution of the current cell state that is assumed to only depend on current state (Equations 1 & 2). The original transition probability matrix (denoted by P) of land use type should be obtained from two former land use maps. CA was used to obtain a spatial context and distribution map based on Markov transitional probability and area by combining multi criteria land allocation to predict land cover change over time. The diamond filter of a kernel size of 5×5 pixels was used to create spatially explicit contiguous weighing factors to measure neighborhood effect or influence. The CA coupled with Markov chain land use predictions of 2016 was made by using the transitional probability area matrix generated for 1973-1992. The validity of the predictions was made with the reference land use maps of 2016 (actual) by evaluating accuracy through the calculation of Kappa index for location and quantity. Based on these validations then visualization was made for 2025 by considering intermediate iterations of 3-year time period.

The CA model can be expressed as,

$$S(t, t+1) = F(S(t), N)$$

where S is the set of discrete cellular states, N is the Cellular field, t and t + 1 indicate the different times, and F is the transformation function of cellular states in local space.

The Markov model is based on the process of the formation of Markov random process systems for the prediction and optimal control theory method. Based on the Bayes conditional probability formula, the prediction of land use changes is calculated by the following equation:

$$P(N) = P(N-1) * P_{ij} \qquad (1)$$

where, $P_{(N)}$ is state probability of any times, and $P_{(N-1)}$ is preliminary state probability.

Transition area matrix can be obtained by,

$$Transition\ area\ Matrix\ P = \begin{bmatrix} P_{11} & P_{12} & P_{13} \\ \vdots & \vdots & \vdots \\ P_{N1} & P_{N2} & P_{NN} \end{bmatrix} \qquad (2)$$

where, P_{ij} is the sum of areas from the i[th] land use category to the j[th] category during the years from start point to target simulation periods; and n is the number of land use types. The transition area matrix must meet the following conditions

i. $0 \leq P_{ij} \leq 1$

ii. $\sum_{i,j=0}^{n} P_{ij} = 1$

Satellite	Year	Resolution			
		Spatial	Spectral	Radiometric	Temporal
Landsat-1	1973	60m	RBV (3), MSS (4)	18 days	6-bits
Landsat-5	1992	30m	MSS (4), TM (7)	16 days	8-bits
IRS	2016	5m	LISS IV (3)	5 days	10-bits

Table 1: Data analyzed in the analysis.

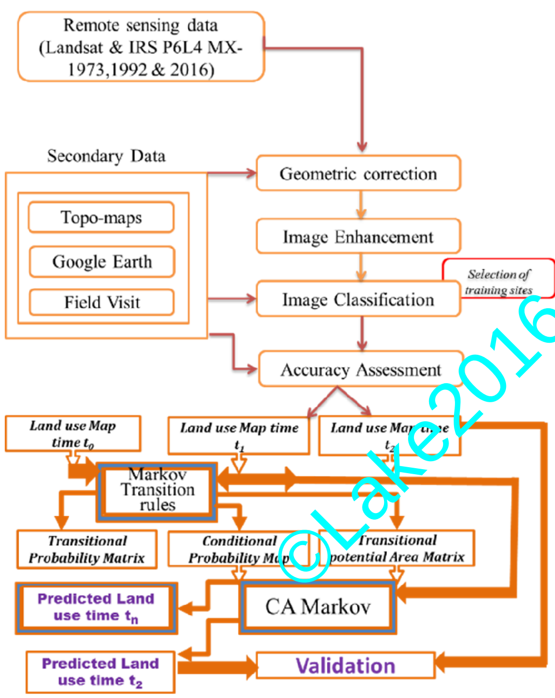

Figure 2: Method followed for LULC analysis.

RESULTS

The land cover land use analyses of selected protected areas and their respective buffer zones illustrate the status and loss of forest cover temporally. The land use analysis has been carried out from 1973-2016 under 9 categories using Gaussian Maximum Likelihood algorithm. The land cover analysis has depicted in Figure 3 (A, B, C) and Figure 4 (A, B, C) highlights loss of vegetation cover from 1973 to 2016. The construction of series of dams from 1980-2005 on Kali river, which flows through ADTR region has resulted in loss of vegetation. The land cover analysis SWLS region had lost vegetation cover from 77.77 to 73.56 %, of vegetation transition. MWLS region shows loss of vegetation cover from 87.46 to 83.98 %, core portion of WLS has not much transition in its cover as compared with buffer. The land use analysis further confirms the changes from 1973 to 2016 due to anthropogenic activities as shown in Figure 5 (A, B, C) and Figure 6 (A, B, C). The ADTR region has lost evergreen forests from 84.43 to 50.51 % (1973-2016) with an increase in plantations (13.51) and agriculture areas (4.66). The eastern part of ADTR has influence of Haliyal taluk's villages and which is major reason for forest loss. The nearby hydro projects and their subsequent developments are also disturbing the region. The increase in deciduous forest cover is depicted in buffer region at the cost of evergreen cover due to various alterations. The increase in built-up area in the buffer region highlights the growth of Dandeli town and other villages as 0.19 to 1.20 % (2016). The SWLS land use analysis highlights evergreen cover has reduced from 27.55 to 22.87% by 2016 with increase in moist deciduous cover and forest plantations as 23.28, 4.26 % respectively. The land use changes were noticed major changes from 1973 to 1992 as compared with 1992-2016. The creation of new roads inside WLS and forest plantations has impact on forest cover. The forest plantations were increased in the Linganmakki reservoir area in the core and buffer regions. The buffer region has more number of villages and horticulture activities (11.64 %) resulting creation of more open spaces with the loss of vegetation. The MWLS land use analysis highlights evergreen cover has reduced from 25.04 to 21.95% by 2016 with increase in moist deciduous cover, the loss was mainly construction of series of dam such as Chakra, Savehaklu inside WLS. The shift from agriculture to horticulture (18.35%) is another major change noticed during 1992-2016 in and around WLS. The move from traditional forming to rubber cultivation has impacted on flora and fauna as well as hydrological regime of entire region. This has resulted in low water yield in the perennial rivers flow through the parks.

The CA_MARKOV analysis has helped in visualization of land use for year 2025 based on previous land use analyses. Simulated and predicted Land uses depicted in Figure 7 & 8 (A, B, C) highlight the three protected areas reflect the same trend as increase in non-vegetative areas. The land use changes as compared to buffer region, ADTR core region has least changes of forest cover but buffer region has lost major forest cover near to existing developments and increase in forest plantations. The region lost evergreen forests from 50.51 to 47.17% (2016-2025) with an increase in plantations and agriculture areas. The population pressure also another factor for forest cover change in SWLS region as the increase in deciduous forest cover depicted in buffer region at the cost of evergreen cover due to various alterations. The increase in built-up area in the buffer region highlights the growth of various towns and other villages. The shift from agriculture to horticulture is noticed at very high rates in buffer areas as constituted 9% of entire region. Projected land use of MWLS highlights loss of vegetation cover during 2016 to 2025 due to anthropogenic activities. The population pressure is also another factor for forest cover change in the buffer region and all agriculture regions are getting transformed to coffee plantations in post 1980's. The increase in horticulture (15.32%) is depicted in buffer region at the cost of forest cover due to various alterations. The increase in built-up area in the buffer region highlights the growth of various towns and other villages.

CONCLUSION

The LULC changes in protected areas will result in imbalance of ecosystem, land productivity and biodiversity. Disturbance corridors created by developmental projects or mismanagement of natural resources is the common phenomenon observed in all three protected areas. Land use analysis highlights loss of evergreen to semi evergreen forest cover and increase in horticulture and forest plantations. MWLS land use analysis highlights evergreen cover has reduced from 25.04 to 21.95% by 2016 with increase in moist deciduous cover, shift from agriculture to horticulture (18.35%). The forest loss from construction of series of dam such as Chakra, Savehaklu inside WLS is another major change noticed. CA-Markov modeling has represented local relations of dynamic systems in simulation and planning purposes for year 2025. The projections generated here are useful to land use planners, resource managers, and conservation practitioners to manage and mitigate impacts through effective planning for conservation. The current study can be further improved by more detailed socio environmental variables integration, location of change and trends of land use changes.

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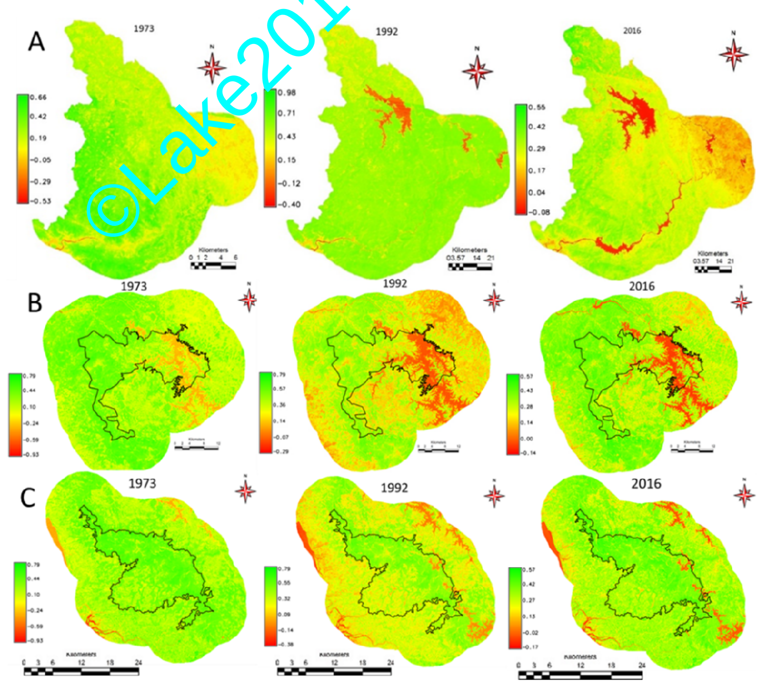

Figure 3 (A, B, C): Land cover analysis of ADTR, SWLS, MWLS regions with 10 km buffer.

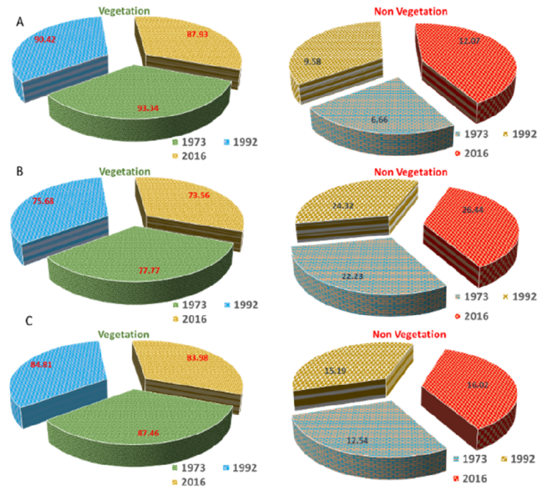

Figure 4 (A, B, C): Land cover analysis of ADTR, SWLS, MWLS regions from 1973-2016.

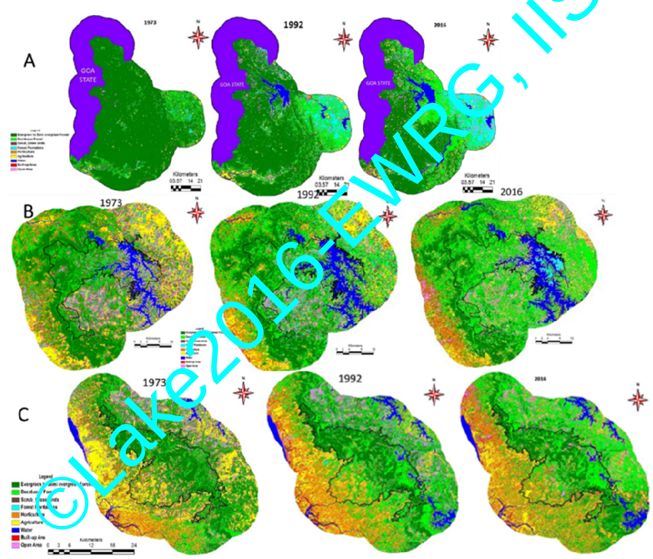

Figure 5 (A, B, C): Land use of ADTR, SWLS, MWLS from 1973-2016.

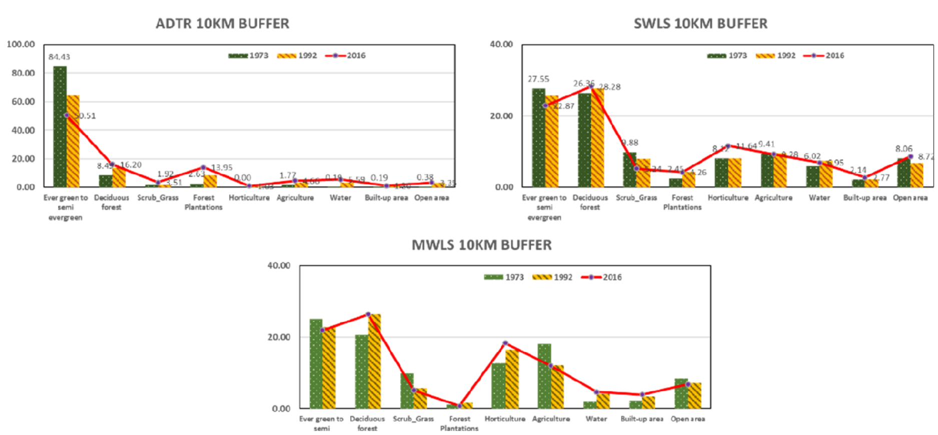

Figure 6 (A, B, C): Land use dynamics of ADTR, SWLS, MWLS.

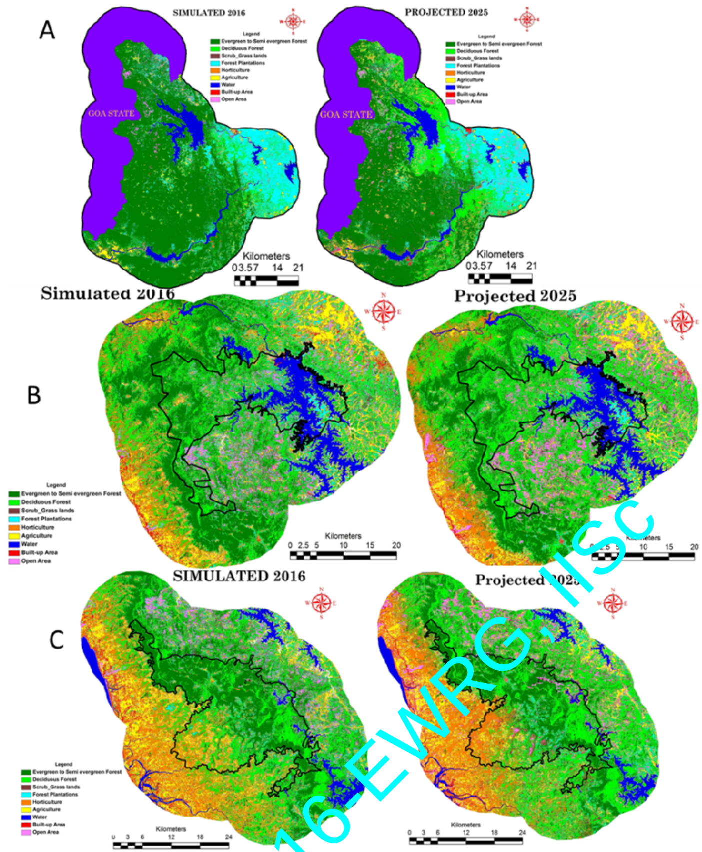

Figure 7 (A, B, C) Simulated and projected land use of ADTR, SWLS, MWLS.

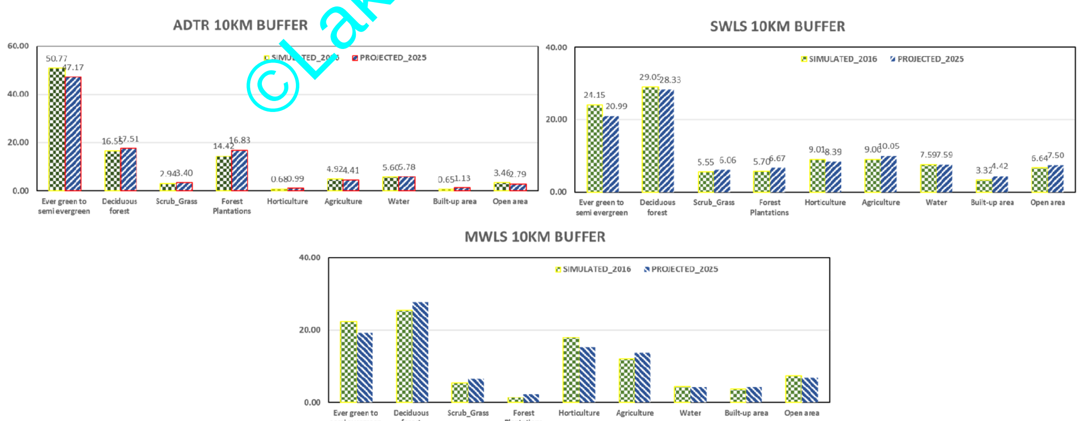

Figure 8 (A, B, C): Simulated and projected land use of ADTR, SWLS, MWLS for 2016 & 2025.