LAKE 2012

LAKE 2012: National Conference on Conservation and Management of Wetland Ecosystems

06th - 09th November 2012
School of Environmental Sciences
Mahatma Gandhi University, Kottayam, Kerala
In association with
Energy and Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore & Advanced Centre of Environmental Studies and Sustainable Development, Mahatma Gandhi University, Kottayam, Kerala

Landscape dynamics of Uttara Kannada district

Bharath Setturu and Ramachandra T V

Energy & Wetlands Research Group, Centre for Ecological Sciences,
Indian Institute of Science
Bangalore – 560 012, INDIA

Tel: 91-80- 22933099/22933503 (extn 107)
Fax: 91-80-23601428/23600085/23600683[CES-TVR]
E-mail: settur@ces.iisc.ernet.in; cestvr@ces.iisc.ernet.in
http://ces.iisc.ernet.in/energy

The land use, land cover (LULC) changes of a region and its interactions with climate, ecosystem processes, biogeochemical cycles, biodiversity provides insights to assess global changes. Remote sensing data with integration of Geographical Information System (GIS) provides spatially consistent data sets with high spatio temporal details which help in detecting and monitoring the drivers for change at various scales. The present study analyses spatio temporal changes in land use pattern of Uttara Kannda district from 1973 to 2010 and also accounts drivers for the rate of change in forest landscape. The monoculture forest management activities, adoption of a market economy crops diversified agricultural activities, such as growing cash crops, fruits and aquaculture. Spatial dependency of land use changes and variations of land development are witnessed in the region by loss of evergreen forest from 87.29% (1973) to 35.42% (2010) and increase in agriculture activities from 2.51% (1973) to 15.96% (2010). The landscape metrics analysis was considered to analyse changes and emphasise the better planning of the region. The outcome of metric analysis shows increase in number of patches (NP), decrease in class area (CA) of forest cover. Computing and defining land use land cover changes are crucial for assessing the effect of land management policies, essential for monitoring and implementation of effective management of the natural resources for environmental protection.

Key words: Land use, Land cover, Remote sensing, GIS, Vegetation indices, land scape metrics**.**

1. Introduction:

Land use land cover (LULC) changes are the strongest drivers of habitat loss, ecosystem alterations and biodiversity changes in forest dominated landscapes. These changes locally alter the ecosystem and globally induce the climate change. LULC changes are driven by the interaction of ecological, geographical, economic, and social factors (Zang and Huang, 2006) in the process of landscape development (Bürgi et al., 2004; Hersperger and Burgi, 2009). These change is always depends on combination of factors specific to that region (Geist and Lambin, 2002, 2006). The temporal data of a region will provides broader view of the LULC changes (Aguayo et al 2009) and its factors. This approach will result whether any natural process also has any impact for the change. Natural disturbances tend to alter forest landscape pattern differently from anthropogenic impacts (Mladenoff, 1993), human induced impacts are quantified as more effect between patches as compared natural change (Hudak et al. (2007). Land degradation caused by LULC change leads to substantial decrease in the biological productivity of the land system, resulting from human activities rather than natural events (Johnson & Lewis, 2006). Loss of natural vegetation cover is often a precedent to soil erosion and decline of the water storage capacity; these modifications of the land system may lead to desertification due to longer term factors such as climate change, triggering short term degradation of ecosystems by humans (Reynolds & Stafford Smith, 2002). Among the human and natural processes occurring in the area, deforestation has been the most important in terms of its spatial extent (Carmona et al., 2010). Forest degradation through logging also has been an important cause of forest loss (Armesto et al., 2009). Disturbance in forested landscapes is referred as fragmentation where forested habitat is reduced into an increasing number of smaller, more isolated, patches (Wilcove et al., 1986). These changes can result in a modification of the microclimate within and surrounding the remnant, intact forest patches (Saunders et al., 1991) and a change in forest ecosystem function and condition (Wickham et al., 2008). Alteration of former natural areas due to human land use can strongly influence biodiversity and ecosystem services (Lindenmayer and Fischer, 2006). The principle information of how LULC changes varies both temporally and spatially and how it affects landscape structure and forest age is extremely important for managing ecosystem services and species conservation (Echeverria et al., 2006; Barlow et al., 2007). Understanding of landscape dynamics and the historic range of variability in ecosystems, key impact of disturbance factors should be considered. Current understanding of the levels and severity of forest change and fragmentation remains incomplete because of not considering all the aspects which are responsible for this change.

Understanding the dynamics of landscape has become important concern from various disciplines, such as landscape ecology, biodiversity conservation and landscape planning. Spatio temporal data acquired through space-borne remote sensors provide a solution due to its efficiency in identification and problem solving approaches. The advantages of remote sensing data is to detect measure and monitor land cover change due to its ability to capture an instantaneous synoptic view of a large part of the Earth's surface and acquire repeated measurements of the same area on a regular basis. Remote sensing data at various temporal scales followed by spatial analysis using GIS technology provides an opportunity to effectively monitor and evaluate the impacts of change over a range of scales, intervals than is possible with expensive and detailed field surveys (Ramachandra et al., 2011; Ramachandra et al 2012). The spectral response of vegetation indices will detects changes in pixel-level vegetation conditions (Leckie et al., 2005; Wulder et al., 2005).

2. **Objective:**The specific objectives of this communication are to
   - (i) assess spatial pattern of land use land cover changes of the landscape;
   - (ii) determine the relative impact of change at each zone level through time and across space.

3. Study area:

Uttara Kannada district lies between 13°55' to 15°31'N latitude and 74°9' to 75°10'E longitude, extending over an area of 10,222 km^2 in the mid-western part of Karnataka state, India (Figure 1). This region is having highest forest cover than among all districts of Karnataka existing with variety of flora and fauna. It is a region of gentle undulating hills, rising steeply from a narrow coastal strip bordering the Arabian Sea to a plateau at an altitude of 500 m with occasional hills rising above 600–860 m (Ramachandra et al., 2010). The district has 11 taluks covering three different zones i.e. coastal lands (Karwar, Ankola, Kumta, Honnavar and Bhatkal taluks), Sahyadrian interior (Supa, Yellapur, Sirsi and Siddapur taluks) and the eastern margin plains (Haliyal, Yellapur and Mundgod taluks). From early 80's the region is started experiencing changes in land use for various developmental activities. This conversion has occurred largely at the expense of forests and grassland (Ramachandra & Shruthi, 2007). Karwar Port, is one of the main ports of Karnataka, total length of 355 meters. Major Industrial Infrastructure of area constitutes 8 Industrial Estates & 1 Industrial Area.

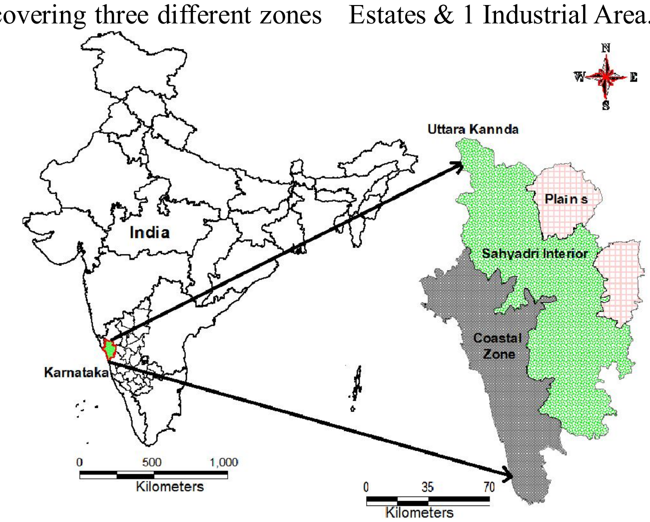

Figure 1: Study area

4. Method:

The RS data used in the study are Landsat MSS (1973), TM (1989, 1999), IRS LISS-IV MX (2010), and Google Earth (http://earth.google.com). Figure 2 details the procedure followed in the study. The temporal remote sensing data of Landsat, IRS satellites were acquired and geometrically corrected for the UTM coordinate system of zone 43 using GCPs (ground control points). Survey of India (SOI) topo-sheets of 1:50000 and 1:250000 scales were used to generate base layers – district and taluk boundaries, water bodies, drainage network, etc. Field data were collected with a handheld Garmin GPS. Since the landscape is dominated by forest, training data is collected for different forest types and land use categories. The Landsat data has been resampled to maintain common resolution across all sensors. The normalised vegetation index (NDVI) is computed at temporal scale to assess the status of vegetation in the district. Among all techniques of land cover mapping NDVI is most widely accepted and applied (Weismiller et al., 1977, Nelson, 1983). NDVI is calculated by using visible Red (0.0.63 – 0.69 µm) and NIR (0.76 – 0.90 µm) bands of Landsat TM which reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Sparse vegetation reflects more visible light and less near-infrared light. NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1). NDVI was calculated using Eq. (1)

$$\mathbf{NDVI = (NIR-R) / (NIR+R)} \quad \ldots (1)$$

The land use analysis was done using supervised classification scheme with selected training sites. Supervised classifier – Gaussian maximum likelihood algorithm is used to classify the temporal data. This method preserves the basic land cover characteristics through statistical classification techniques using a number of well-distributed training pixels. GRASS (Geographical Analysis Support System) a free and open source software having robust support of processing both vector, raster files has been used for this analysis, accessible and downloadable at http://wgbis.ces.iisc.ernet.in/grass/index.php. Spectral classification inaccuracies are measured by a set of reference pixels. Based on the reference pixels, confusion matrix, kappa (κ) statistics and producer's and user's accuracies were computed. Accuracy assessment and kappa statistics are included in table 3. These accuracies relate solely to the performance of spectral classification. The study is carried out at macro and micro scales, i.e. by considering the whole landscape as a single unit and zone based analysis. The spatial analysis was done according to the zones in order to access the detailed land use land cover pattern.

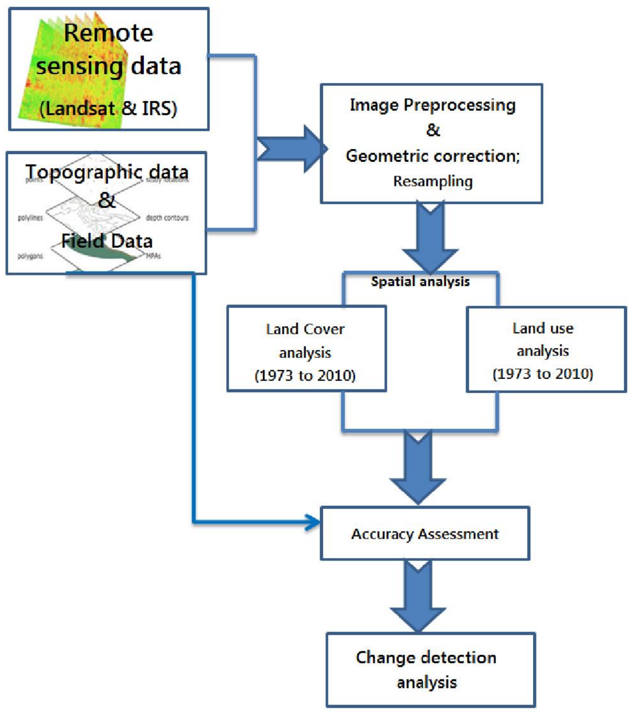

Figure 2: Method followed in the study

5. Results:

The land cover analysis was done by computing NDVI at temporal scale reveals the transition of vegetation from 1973 to 2010. Year 1973 shows 97.82% of the area was under vegetation whereas in 2010 it is 89.92%. The non-vegetated areas have increased by 10.08% (2010) from 2.18 % (1973). The temporal variation of land cover is shown in table 1 and figure 3.

Year	% vegetation	%non-vegetation
1973	97.82	2.18
1989	96.13	3.87
1999	94.33	6.67
2010	89.92	10.08

Table 1: temporal change in land cover

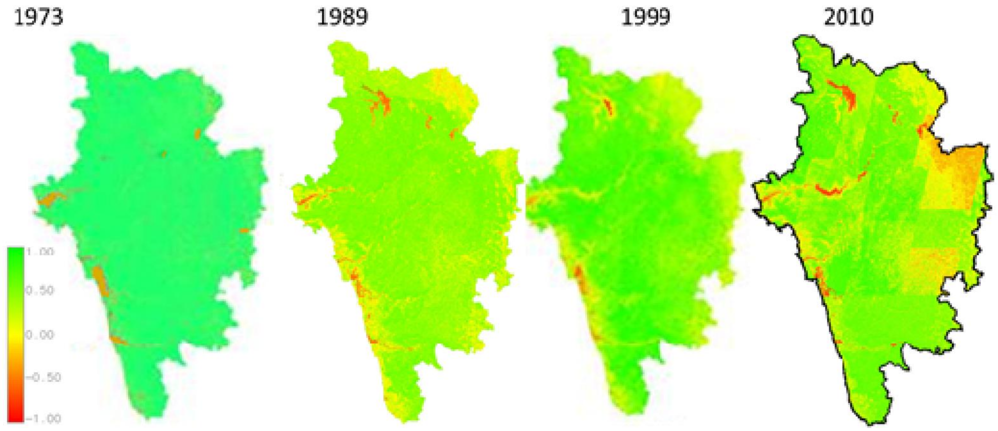

Figure 3: Land cover analysis – NDVI

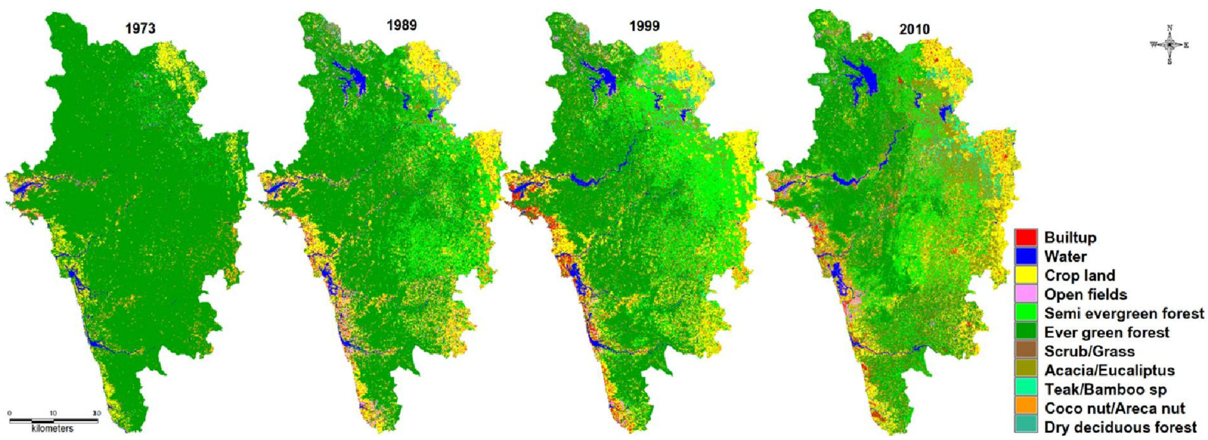

Figure 4 (a): Land use analysis from 1973 to 2010

Year / Category	1973		1989		1999		2010	
	Ha	%	Ha	%	Ha	%	Ha	%
Built-up	1944	0.19	11,569	1.13	15,991	1.56	27171	2.64
Water	13,012	1.28	19,454	1.89	26,391	2.57	26232	2.54
Crop land	53,822	5.25	175,236	17.06	170,886	16.63	164187	15.96
Open fields	4113	0.40	40,336	3.93	19,116	1.86	22793	2.21
Semi evergreen forest	12700	**1.24**	85,087	**8.28**	208,677	20.31	160992	15.64
Evergreen forest	892923	**87.11**	592,238	**57.65**	447,475	43.56	364535	35.42
Scrub/grass	8028	0.78	33,843	3.29	51,439	5.01	37223	3.62
Acacia_pl / Eucaliptus	18385	1.79	46,963	4.57	55,292	5.38	146975	14.28
Teak/ Bamboo_pl	242	0.02	10,702	1.04	18,463	1.80	28660	2.78
Coconut_Arecanut_pl	11938	1.16	3001	0.29	10,839	1.06	49129	4.77
Dry deciduous forest	711	0.76	8831	0.86	2703	0.26	1424	0.14

Table 2: temporal change in land use

The status of land and its transition is accounted by land use analysis at different time scales. The analysis clearly depicts he loss of vegetation cover from 1973 to 2010. The primeval evergreen forest cover is reduced from 87.11% (1973) to 35.42% (2010). This is mainly due to anthropogenic activities than natural processes. The built-up area has increased from 0.19% (1973) to 2.64% (2010). The intensified agriculture activities also aggravating the deforestation rate in this region. The table 2 and figure 4 (a) clearly describes the transition of landscape from 1973 to 2010. The increase in plantation of exotic species led to removal of primeval forest cover. The accuracy assessment was included in table 3. The field data and Google earth data sets are used for analysing accuracy and the analysis shows that accuracy ranges from 87 to 93%.

Overall Accuracy	Kappa
87.38	0.81
91.25	0.86
92.47	0.88
87.88	0.82

Table 3: Accuracy assessment

The forest loss is not uniform across the district since the effects of anthropogenic activities vary across different regions. To account these variations the zone wise analysis was considered. The change at temporal scale is accounted to investigate the effect of drivers for the change with respect to each zone. The figure 5 (a, b) explains temporal variation of deforestation from 1973 to 2010 in coastal region. Population growth and consequent changes in land use (forest to agriculture) and developmental activities have led to the decline in forest cover in this region. The hydroelectric projects in Karwar, Honnavar taluks and Nuclear power generation as well as Seabird novel base projects in Karwar taluk can be attributed for this change. It is evident from this study the built-up area is increased from 0.32% (1973) to 3.74% (2010) at the loss of evergreen forest from 80.16% (1973) to 49.16% (2010).

The Sahyadri interior region is having the major forest cover and undulating terrain. The region has tropical evergreen forest and semi-evergreen forest to moist deciduous forest cover with protected areas for endemic flora and fauna. The temporal analysis reveals of changes due to due to the hydroelectric projects situated at Supa taluk and intensive horticulture activities in Siddapur, Sirsi taluks. The evergreen forests are lost from 95.45% (1973) to 40.71% (2010) due to induced changes (figure 6a, b). The intensified agriculture activities are observed due to perennial water availability. The eastern and north-western parts Uttara Kannda district comprises of extensive teak planted area tending to scrub type at the border of Dharwad district. The forests towards the west yield high quality timber (teak and hardwoods). There are patches of evergreen forests towards the western side in the lower portion of the river valleys. It is observed that the plains are more prone to anthropogenic interaction than any other regions of the district (figure 7(a, b)). The loss of evergreen forest cover from 73.2% (1973) to 6.5% (2010) shows the severity in deforestation pattern. The intensified agriculture activities can be observed as 14.08% (1973) to 36.56% (2010).

To understand the causal factors of land cover, dynamics, land use changes due to the implementation of various developmental projects in the Uttara Kannda district (figure 8) were considered Figure 8 explains the major infrastructure developments of this region which are showing impact on local ecology. To provide overview of changes, the temporal analysis was done by considering there major projects. The buffer based analysis was considered to explain how these major projects influences on the surrounding areas. The Project sea bird is considered in coastal zone, Supa hydroelectric project is considered in Sahyadri zone and West coast paper mill is considered in eastern region.

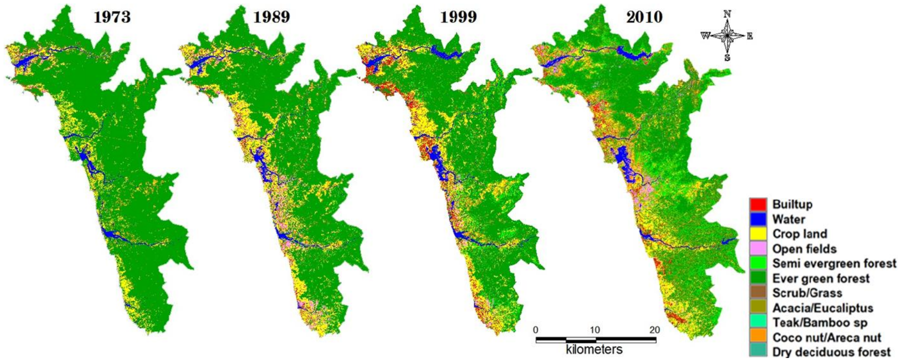

Figure 5 (a): temporal change of land use in Coastal zone

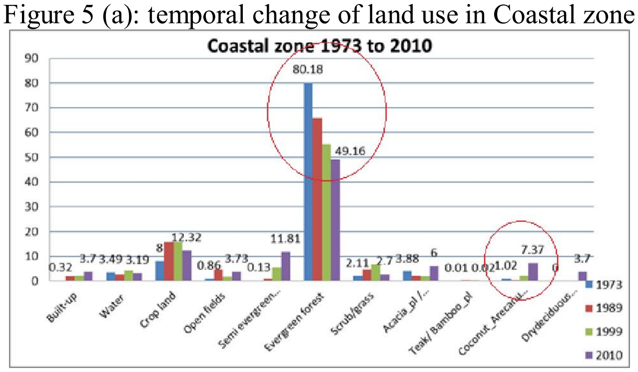

Figure 5 (b): the land use dynamics of Coastal zone

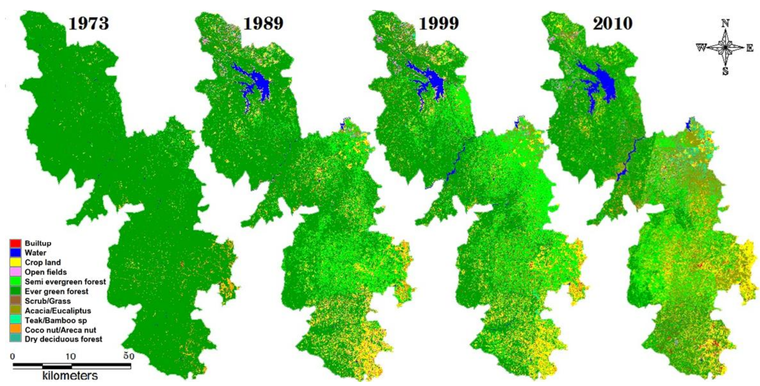

Figure 6 (a): temporal change in land use of Sahyadri Interior

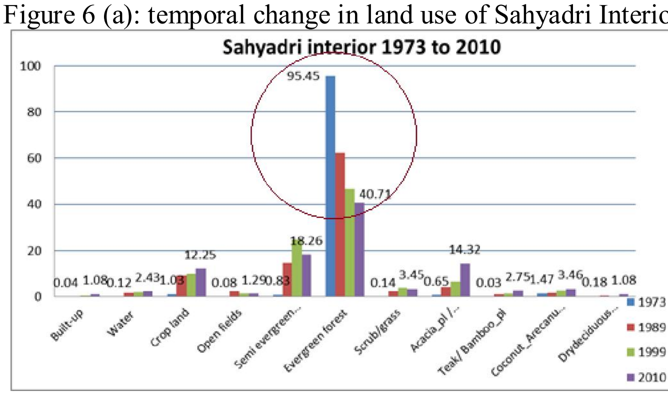

Figure 6 (b): the land use dynamics of Sahyadri Interior

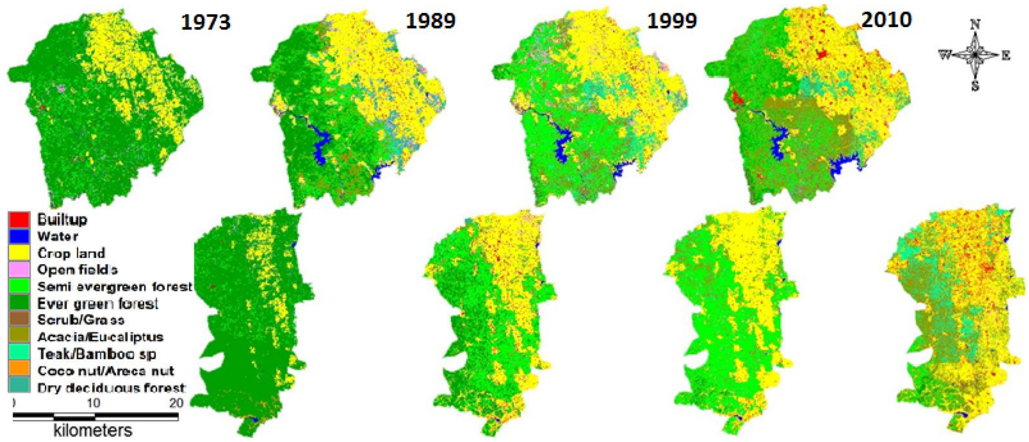

Figure 7 (a): temporal change in land use of Plains

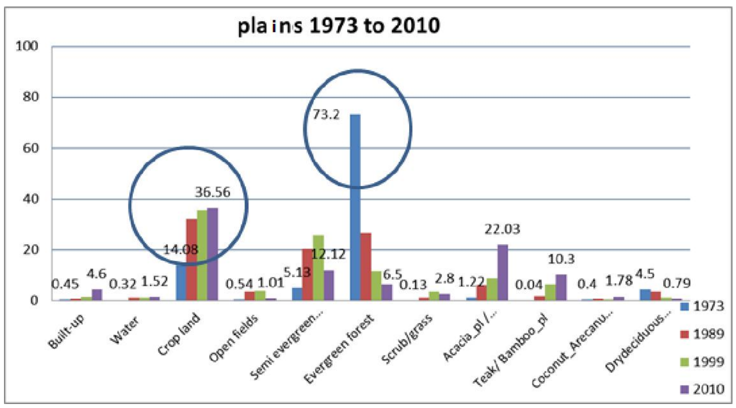

Figure 7 (b): the land use dynamics of Plains

Figure 8: Developmental projects of Uttara Kannada district

- Project Seabird (INS Kadamba) is an Indian Navy base located near Karwar in Karnataka, a larger naval base in Asia and has an exclusive military harbour. Spread over 11,200 acres and with a 26km-long coastline.
- Supa Dam is the second largest dam in the state of Karnataka,built across the Kali river in Joida Taluk of Uttara Kannada District in India. The construction started in 1974 and ended in 1987. It has a catchment area of 1057 Sq.Kms and the live storage capacity is 145 Tmcft. (Thousand Million Cubic Feet). The reservoir has two saddle dams of length 705 Mtrs and 940 Mtrs. The power house at the foot of the dam has two electricity generators of fifty megawatt each.
- The West Coast Paper Mills, Dandeli situated in the heart of thick forests on the banks of Kali river and getting required supply of raw materials, perennial availability of water. Started in 1955 in the vicinity of rail and road linkages and the assurance of state government of Maharashtra for continued supply of forest-based raw materials, availability of water from the perennial Kali river, assured power supply from the state grid,. The mill was originally designed to produce 18,000 tpa (tonnes per annum) of writing, printing and packaging paper in 1959 and periodically expanded to reach current production levels of 178500 tpa.

The spatio temporal analysis provides how these developmental projects changing the landscape from 1973 to 2010 figure (9 (a, b, c)) and table (4 (a, b, c)). The built-up area is increased from 1.87% (1973) to 33.74% (2010) within project area. With respect to 2km and 4km buffers also it shows the increasing trend. The evergreen forest is decreased from 35.01%(1973) to 5.79% (2010) within project area, even the 2km, 4km buffer areas also showing drastic changes in the evergreen forest cover. The region shows increase in scrub forest because of removal of primeval forest.

Land use category	**Project area**		**2km**		**4km**	
Year	**1973**	**2010**	**1973**	**2010**	**1973**	**2010**
Built-up (%)	1.72	33.85	0	5.17	0.12	3.54
Water	14.84	0.99	0	0	0	0.02
Agriculture	12.87	16.87	5.53	8.08	1.62	0.79
Open space	35.56	15.98	4.33	3.81	6.09	2.33
Semi ever green to moist deciduous	0	4.83	0.10	13.49	0	12.72
Evergreen forest	35.01	5.79	90.04	55.94	92.17	63.72
Scrub forest/Grass lands	0	11.25	0	0.26	0	0.77
Acacia Plantations	0	2.90	0	4.43	0	9.97
Teak / Bamboo plantations	0	0		0	0	0
Coco nut/Areca nut plantations	0	7.53	0	8.82	0	6.14
Dry deciduous forest	0	0	0	0	0	0

Table 4(a): temporal change in Project sea bird Area (Project area, 2km Buffer, 4km Buffer)

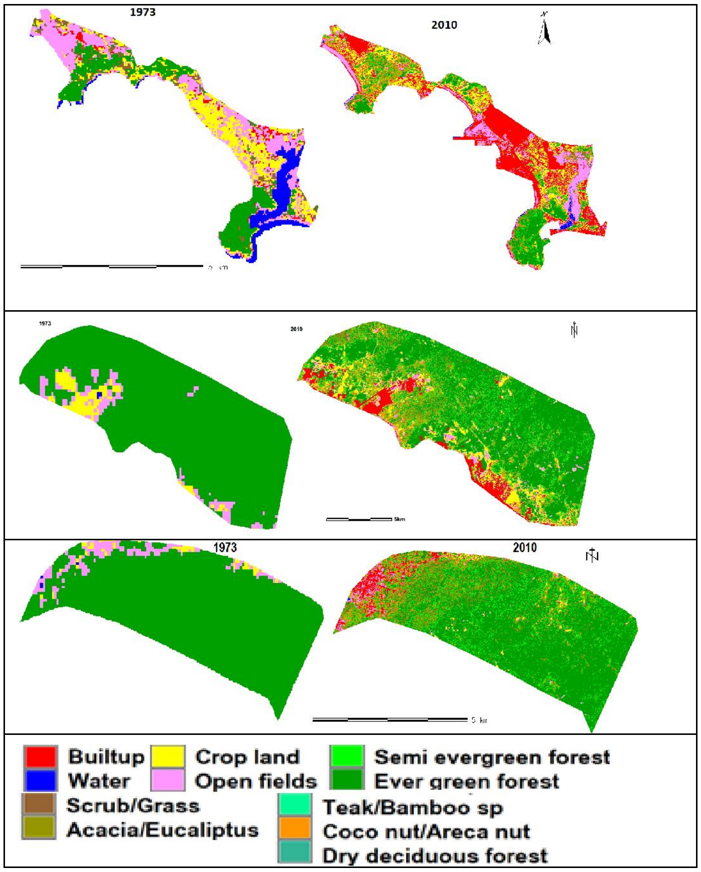

Figure 9(a): temporal change in Project sea bird Area (Project area, 2km Buffer, 4km Buffer)

The Supa hydroelectric project was implemented in Sahyadri Interior region. This region is thick evergreen patches in 1973 and the construction was started in 1974. The spatio temporal analysis shows of the evergreen forest cover loss and increase in built-up area. The 1km, 5km, 10km buffer is considered to account these changes with respect to surroundings. The built-up area is increased from 0.18% (1973) to 3.24(2010) because of establishment of work force colonies. The evergreen forest cover has decreased from 94.32% (1973) to 32.23% (2010) within the 1km buffer. This degradation can also clearly identified in 5km, 10km buffer regions.

Land use category	**1km**		**5km**		**10km**	
Year	**1973**	**2010**	**1973**	**2010**	**1973**	**2010**
Built-up (%)	0.18	3.24	0.05	0.13	0.16	0.65
Water	4.55	42.57	0.75	37.8	0.45	17.9
Agriculture	0.96	0.48	1.62	1.03	1.27	4
Open space	0	2.32	0	0.58	0.07	1.71
Semi ever green to moist deciduous	0	7.28	2.86	6.14	3.71	11.11
Evergreen forest	94.32	32.23	94.72	48.15	94.34	51.07
Scrub forest/Grass lands	0	6.28	0	1.65	0	3.66
Acacia Plantations	0	5.12	0	4.33	0	8.06
Teak / Bamboo plantations	0	0	0	0	0	0.28
Coco nut/Areca nut plantations	0	0.48	0	0.19	0	1.56
Dry deciduous forest	0	0	0	0	0	0

Table 4(b): temporal change in Supa hydroelectric power project area (1km, 5km Buffer, 10km Buffer)

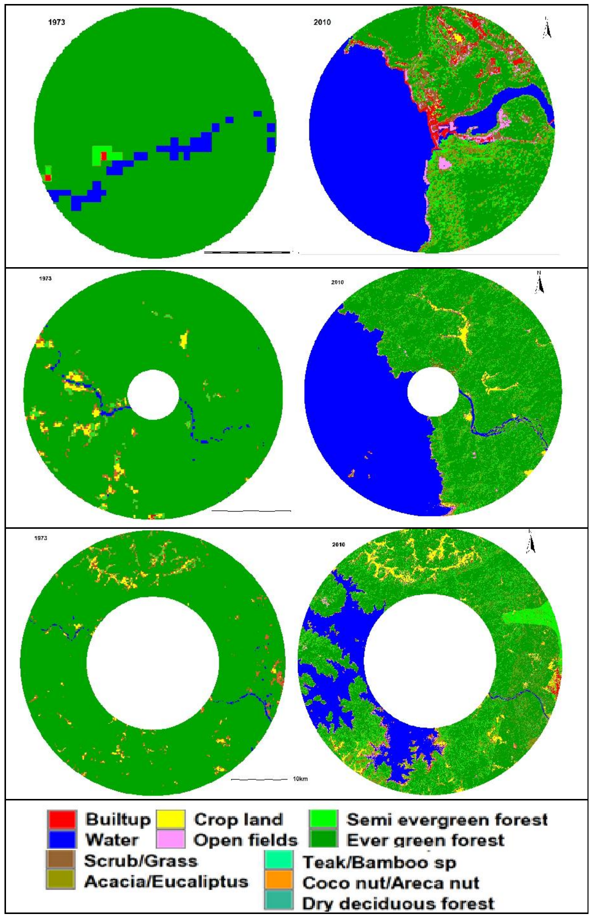

Figure 9(b): temporal change in Supa hydroelectric power project area (1km, 5km Buffer, 10km Buffer)

The west coast paper mills region is considered and the project area with its surroundings were analysed at temporal scale. The result clearly shows changes in this region because of anthropogenic activities. The figure 9 (c) shows with in 1km of project area shows intensified built-up area and even with in 5km. The temporal analysis shows that there is loss of semi evergreen and evergreen forest cover. It is observed that to meet the demand of raw material for the paper mills in and around area was converted to plantations, which is shown 4.47% with in 1km and 24.74% within 5km region.

Land use category Year	1km		5km	
	1973	2010	1973	2010
Built-up (%)	3.04	32.63	0.2	1.85
Water	5.01	2.57	4.75	1.38
Agriculture	2.48	10.42	0.69	4.59
Open space	0	1.57	0	0.5
Semi ever green to moist deciduous	48.13	34.12	7.11	33.73
Evergreen forest	41.35	2.44	87.25	24.09
Scrub forest/Grass lands	0	3.76	0	3.8
Acacia Plantations	0	4.77	0	24.74
Teak / Bamboo plantations	0	1.07	0	3.63
Coco nut/Areca nut plantations	0	6.65	0	1.69
Dry deciduous forest	0	0	0	0

Table 4(b): temporal change in West coast paper mill area (1km, 5km Buffer)

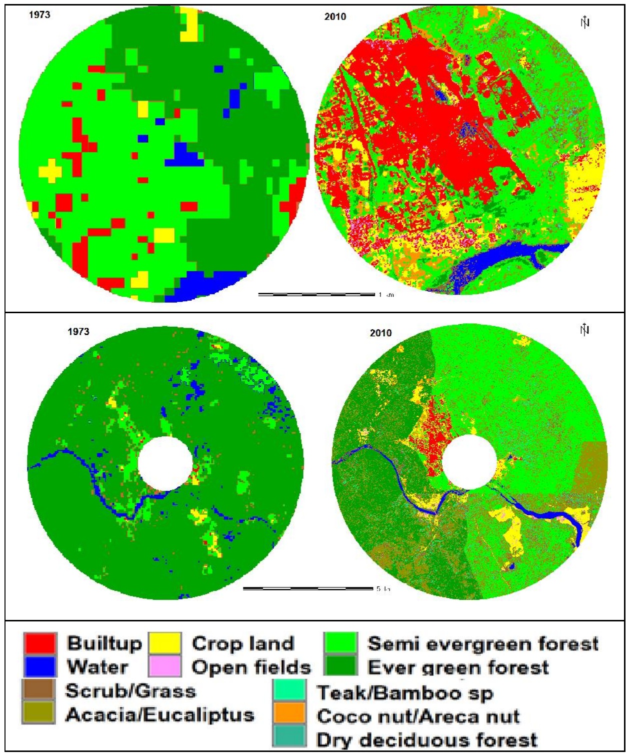

Figure 9(c): temporal change in West coast paper mill area (1km, 5km Buffer)

6. Conclusion:

The spatio temporal landscape dynamics analysis revealed the loss of primeval evergreen forest from 1973 to 2010. The land cover analysis results increase in non-vegetated area from 2.18%(1973) to 10.08% (2010). The temporal forest transition shows evergreen forest cover is decreased from 87.11% (1973) to 35.42% (2010) and increase in agriculture land as well as built-up area. The land cover analysis revealed increase in non-vegetated area from 1973 to 2010. The zone based analysis that coastal and plains have undergone higher land use changes having more deforestation rates than Sahyadri interior. The plantation of exotic species of vegetation led to the loss of primeval forests in the region. The temporal changes with respect to developmental projects were supplemented with three areas of each zone. Large scale land cover changes were observed with the implementation of large scale projects. Built up area has increased from 0.48 (1973) to 3.24 (2010) % in the case of Supa dam, 1.72 (1973) to 33.85 (2010)% due to project Seabird and area under evergreen forests declined from 45.85%(1973) to 2.48 (2010)% due to West Coast paper mill. Considering the impending climate change due to global warming, it is essential to adopt holistic approaches in the forest resources management to ensure sustainability. Regions degraded due to various developmental projects need to be restored with native species. There is a need to bring awareness among local communities of cultivating in regions above 30% slope to minimise episodes of landslides.

7. Acknowledgement:

We are grateful to Ministry of Environment & Forest, Ministry of Science and Technology, Government of India, Karnataka Biodiversity Board, Western Ghat Task Force, Government of Karnataka and Indian Institute of Science for the financial and infrastructure support.

8. References:

[1] Aguayo, M., Oauchard, A., Azócar, G., Parra, O., 2009. Land use change in the south central Chile at the end of the 20th century. Understanding the spatio-temporal dynamics of the landscape. Rev. Chil. Hist. Nat. 82, 361–374.

[2] Armesto, J., Smith-Ramírez, C., Carmona, M., Celis-Diez, J., Díaz, I., Gaxiola, A., Gutierrez, A., Nú˜nez-Avila, M., Pérez, C., Rozzi, R., 2009. Old-growth temperate rain forests of South America: conservation, plant-animal interactions, and baseline biogeochemical processes. Old-growth forests: function, fate and value. In: Wirth, C., Gleixner, G., Heimann, M. (Eds.), Ecological Studies, vol. 207. Springer, New York, Berlin, Heidelberg, 367–390.

[3] Ramachandra, T.V., Bharath Setturu, Bharath H Aithal, 2012, Peri-Urban to Urban Landscape Patterns Elucidation through Spatial Metrics, International Journal of Engineering Research and Development; 2(12), 55.

[4] Bürgi, M., Hersperger, A., Schneeberger, N., 2004. Driving forces of landscape change—current and new directions. Landscape Ecol. 19, 857–868.

[5] Carmona, A., Nahuelhual, L., Echeverría, C., Báez, A., 2010. Linking farming systems to landscape change: an empirical and spatially explicit study in southern Chile. Agr. Ecosyst. Environ. 139, 40–50

[6] Geist, H., Lambin, E., 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52 (2), 143–150.

[7] Geist, H., Lambin, E., 2006. Land use and land change: local processes, global impacts. Springer, Berlin, GE, 222.

[8] Hersperger, A., Bürgi, M., 2009. Going beyond landscape change description: quantifying the importance of driving forces of landscape change in a central Europe case study. Land Use Policy 26, 640–648.

[9] Hudak, A.T., Morgan, P., Bobbitt, M., Lentile, L., 2007. Characterizing stand-replacing harvest and fire disturbance patches in a forested landscape: a case study from Cooney Ridge Montana. In: Wulder, M.A., Franklin, S.E. (Eds.), Understanding Forest Disturbance and Spatial Pattern: Remote Sensing and GIS Approaches. CRC Press (Taylor and Francis), Boca Raton, FL, pp. 209–231, 246.

[10] Johnson, D.L., Lewis, L.A., 2006, Land degradation: Creation and destruction Rowman and Littlefield, New York.

[11] Leckie, D.G., Cloney, E., Joyce, S.P., 2005. Automated detection and mapping of crown discoloration caused by jack pinebudwormwith 2.5mresolution multispectral imagery. International Journal of Applied Earth Observation and Geoinformation 7, 61–77.

[12] Lindenmayer, D., Fischer, J., 2006. Habitat Fragmentation and Landscape Change. Island Press, Washington, DC, 328.

[13] Mladenoff, D.J., White, M.A., Pastor, J., Crow, T.R., 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications 3, 294–306.

[14] Nelson R.F, 1983. Detecting forest canopy change due to insect activity using Landsat MSS, Photogram. Eng. Remote Sensing 49 (1983), 1303–1314.

[15] Ramachandra T.V. and Shruthi B.V. 2007. Spatial mapping of renewable energy potential, Renewable and Sustainable Energy Reviews, 11(7):1460-1480.

[16] Ramachandra. T.V and Uttam Kumar, 2011. Characterisation of Landscape with Forest Fragmentation Dynamics, Journal of Geographic Information System, 3, pp: 242-254.

[17] Ramachandra T. V., Uttam Kumar, Bharath H. Aithal, Diwakar P. G. and Joshi N. V., 2010. Landslide Susceptible Locations in Western Ghats: Prediction through OpenModeller, Proceedings of the 26th Annual In-House Symposium on Space Science and Technology, ISRO-IISc Space Technology Cell, Indian Institute of Science, Bangalore, 65-74.

[18] Reynolds, J.F., Stafford Smith, D.M., (Eds.), 2002, Global desertification: Do humans cause deserts? Dahlem University Press, pp. 1–22.

[19] Saunders, D.A., Hobbs, R.J., Margules, C.R., 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5, 18–32.

[20] Wickham, J., Riitters, K., Wade, T., Homer, C., 2008. Temporal change in fragmentation of continental US forests. Landscape Ecology 23, 891–898.

[21] Wilcove, D.S., McLellan, C.H., Dobson, A.P., 1986. Habitat fragmentation in the temperate zone. In: Soulé, M. (Ed.), Conservation Biology: Science of Scarcity and Diversity. Sinauer Associates, Sunderland, MA, 237–256.

[22] Wulder, M.A., White, J.C., Coops, N.C., Han, T., Alvarez, M.F., 2005. A Protocol for Detecting and Mapping Mountain Pine Beetle Damage from A Time-series of Landsat TM or ETM+ Data. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, p. 70. Report nr Version 1.0

[23] Weismiller R.A, S.J. Kristof and D.K. Scholtz, 1977. Change detection in coastal zone environments, Photogram. Eng. Remote Sensing 43 (1977), 1533–1539.

[24] Zang, S., Huang, X., 2006. An aggregated multivariate regression land-use model and its application to land-use change processes in the Daqing region (northeast China). Ecol. Model. 193, 503–516.

[25] Barlow, J., Mestre, L.A.M., Gardner, T.A., Peres, C.A., 2007. Value of primary, secondary and plantation forests for Amazonian J. birds, Biol. Conserv., 136, 212–231.

[26] Echeverria, C., Coomes, D., Salas, J., Rey-Benayas, J.M., Lara, A., Newton A., 2006. Rapid deforestation and fragmentation of Chilean temperate forests, Biol. Conserv., 130, 481–494.