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LAND USE LAND COVER (LULC) DYNAMICS IN UTTARA KANNADA DISTRICT, CENTRAL WESTERN GHATS

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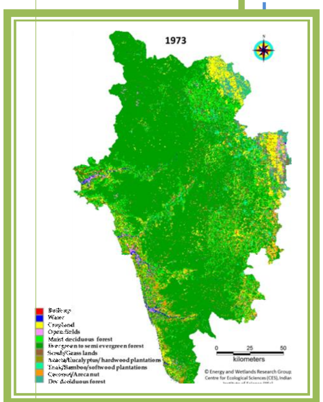

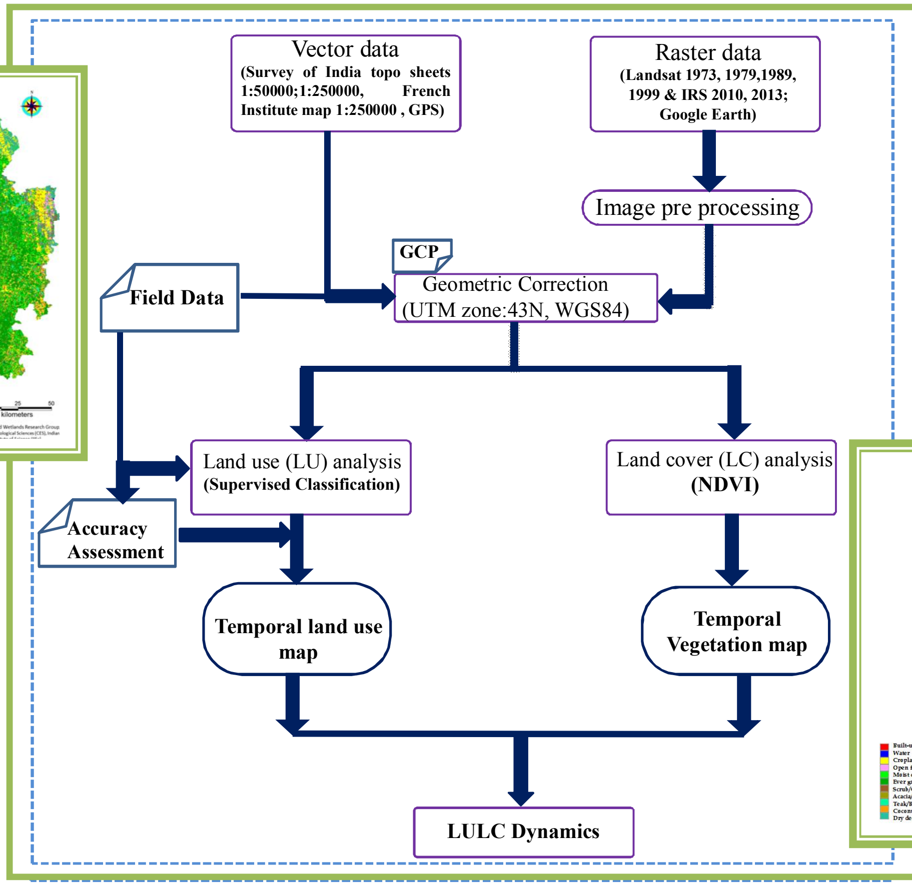

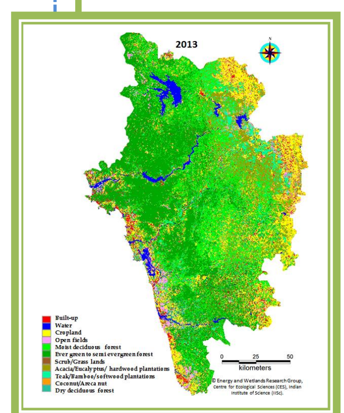

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ENVIS Technical Report: 56

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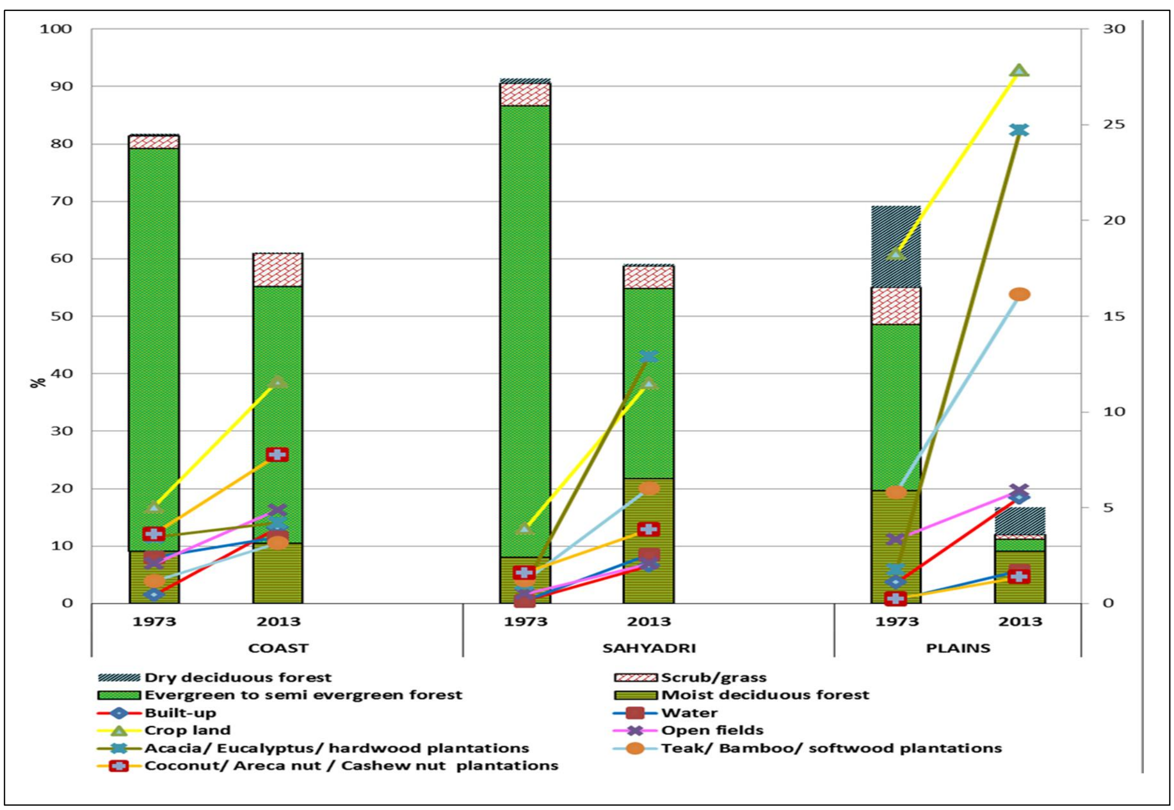


LAND USE LAND COVER (LULC) DYNAMICS IN UTTARA KANNADA DISTRICT, CENTRAL WESTERN GHATS

Summary:

Land use Land cover (LULC) dynamics is a major concern, as the abrupt changes has a negative impact on ecology, climate, regional hydrology, and also people's livelihood in the region. LULC dynamics are specific to a region and vary from region to region. Land Cover refers to the observed physical cover on the earth's surface. Land cover essentially distinguishes the region under vegetation with that of non-vegetation. Land use refers to use of the land surface through modifications by humans and natural phenomena. Land use can be classified into various classes such as water bodies, built up, forests, agriculture, open lands, sand, soil, e*tc*. Land use modifications alter the structure of the landscape and hence the functional ability of the landscape. The modification includes conversion of forest lands, scrublands to agricultural fields, cultivation lands to built-up, construction of storage structures for water bodies leading to submergence of land features that may vary from small scale to large scale.

Land use and land cover patterns and their changes over time for Uttara Kannada district, Karnataka are quantified with the spatial data acquired through space borne sensors. Remote sensing data with synoptic repetitive coverage aids in understanding the landscape dynamics. The spatial data have been analysed using Geographic Information System (GIS). Changes in land use, land cover (LULC) have been analysed using temporal remote Sensing data with collateral data (field data, the Survey of India topographic maps, Google Earth data) through GIS. Vegetation cover (land cover) assessment was done by computing Normalised Difference Vegetation Index (NDVI) show the decline of vegetation cover from 92.87% (1973) to 83.44% (in 2013). Land use analysis reveal distressing trend of deforestation in the district, evident from the reduction of evergreen-semi evergreen forest cover from 67.73% (1973) to 32.08% (2013). Taluk-wise analysis reveal similar trend for evergreen - semi evergreen forest cover during 1973 to 2013; Ankola (75.66 to 55.33%), Bhatkal (61.37 to 30.38%), Honnavar (70.63 to 35.71%), Karwar (72.26 to 59.70%), Kumta (62.89 to 29.38%), Siddapur (71.42 to 23.68), Sirsi (64.89 to 16.78), Supa (93.56 to 58.55%), Yellapur (75.28 to 18.98%), Haliyal (35.45 to 2.59%), Mundgod (20.63 to 1.52).

Forest cover has declined from 81.75 (1973) to 60.98% (2013) in the coastal zone, 91.45 (1973) to 59.14% (2013) in the Sahyadrian interior, and 69.26 (1973) to 16.76% (2013) in plains zone. Changes in the landscape structure (through large scale land use changes) have altered functional abilities of an ecosystem evident from lowered hydrological yield, disappearing perennial streams, higher instances of human–animal conflicts, declined ecosystem goods, etc. This necessitates the restoration of native forests in the region to ensure water and food security apart from livelihood of the local people.

Keywords: Land use, land cover, remote sensing data, Geoinformatics, change analysis

INTRODUCTION:

Landscapes are composed of many dynamic components which have their own dynamics. A natural landscape has complex ecological, economic, and cultural qualities on which human and other life forms depend directly. Landscape is heterogeneous land area of interacting systems which forms an interconnected system called ecosystem (Forman & Gordron, 1986). The functional aspects (interaction of spatial elements, cycling of water and nutrients, bio-geo-chemical cycles) of an ecosystem depends on its structure (size, shape, and configuration) and constituent's spatial patterns (linear, regular, aggregated). The status of a particular land scape is derived from land use land cover [LULC] information. Land use land cover information of a region provides a base for accounting the natural resources availability and its utilization. The information pertaining to LULC provides a framework for decision making towards sustainable natural resources management. The analysis of the LULC change addresses issues like climate change, deforestation, soil erosion by water and wind, salinization etc.

Land use, Land cover [LULC] dynamics: Land cover [LC] relates to the discernible Earth surface expressions, such as vegetation or non-vegetation (soil, water or anthropogenic features) indicating the extent of Earth's physical state in terms of the natural environment (Lambin et al., 2001, Ramachandra et al., 2012). Variations in topography, vegetation cover, and other physical characteristics of the land surface influence surface-atmosphere fluxes of sensible heat, latent heat, and momentum of heated air particulates caused by conduction, convection and radiation, which in turn influence weather and climate. Land use [LU] is an expression of human uses of the landscape, e.g. for residential, commercial, or agricultural purposes, etc. Land cover changes induced by human and natural processes play a major role at global as well as at regional scale patterns of the climate and biogeochemistry of the Earth system. Land cover information is vital for regional planning and management activities and has been considered as an essential element for modeling and understanding the earth as a system (Ramachandra and Shruthi, 2007).

Monitoring LULC plays an important role at the local/regional as well as global level to understand the dynamics associated with the Earth. Monitoring and management of natural resources requires timely, synoptic and repetitive coverage over large area across various spatial scales that help in assessing the temporal and spatial changes. Remote sensing data acquired at regular intervals through space borne sensors since 1970's provides an up to date, reliable, spatial data, which are useful for LULC analysis. Geographic Information System (GIS) helps in the compilation, analysis and management of spatial data with attribute information. Remote sensing data with better spectral and spatial resolution (Multi Spectral data, Hyperspectral data, etc.) and GIS technologies play an important role in evaluating spatially the natural resource dynamics for the management and planning of activities such as land-use development, natural resource exploitation and engineering projects.

Land use changes alter the homogeneous landscape into heterogeneous mosaic of patches. The LULC changes are due to natural as well as human induced alterations. These changes are highly dynamic and characterized by heterogeneous landscape facilitating socioeconomic–environmental interactions. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics initiate changes in land cover. Globally, land cover is altered principally by direct anthropogenic use such as agriculture, livestock raising, forest harvesting & management, population change, urbanisation and other developmental activities (Meyer, 1995). 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 with natural changes (Hudak et al. 2007). The undisturbed (or wilderness) areas represent only 46% of the earth's land surface (Mittermeier et al., 2003). Forests covered about 50% of the earth's land area 8000 years ago, as opposed to 30% today (Ball, 2001).

LULC changes include the conversion of an area (land transformation) from one land use type to another, as well as decline in the biological or economic productivity and complexity of the land. LULC changes due to the human management of ecosystems modify the biogeochemical cycles, climate, and hydrology of a primeval ecosystem (Ramachandra and Savitha, 2008), driving biodiversity loss through habitat fragmentation and destruction. These changes directly impact biodiversity of a region (Sala et al., 2000), leads to soil degradation, induces local climate change (Chase et al., 1999) as well as global warming (Houghton et al., 1999; Tolba et al., 1992). These changes alter the ecosystem services by affecting the ability of biological systems to support human needs and posing challenges to the decision makers. LULC changes also determine the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson et al., 1995) in the process of landscape development (Bürgi et al., 2004; Hersperger and Burgi, 2009).

Humans have left an impressive mark on the world's land over the past several centuries. Modifying land to obtain food and other essentials has been considered as a common practice of humans from thousands of years, the current rates, extents and intensities of LULC changes are far greater than ever in history, driving unique changes in ecosystems and environmental processes at local, regional and global scales (Turner et al., 1994; Ellis, 2011). With the dramatic growth in world population, need for greater food production has led to a massive increase in cropland. Almost 40 percent of Earth's land surface had been converted to cropland and permanent pasture by early 1990's. This conversion has occurred largely at the expense of forests and grassland (Ramachandra et al., 2007). Changes in forested landscapes have been more sudden from middle of the last century and have occurred at a broader scale due to policy impetus to industrialisation, urbanization and globalization (Antrop, 2005; Calvo-Iglesias et al., 2008). Socioeconomic processes are a driving force for the spatial patterns of the land transformation through time (Potter and Lobley, 1996). In forest dominated landscapes, because of soil fertility and a market economy, household actions cycled between deforestation, agricultural intensification, pasture formation which ultimately lead to land abandonment. The human induced changes with respect to forest dominated land scape transforms dense evergreen forests into scattered trees or savannah-like ecosystems and scrublands over the time. Deforestation is a phenomenon caused complex combination of processes that vary in space and time (Lambin, 1997) and it leads to equally complex environmental and socioeconomic consequences.

Ecosystems provide bundles of ecosystem services i.e., the benefits humans obtain from ecosystems that interact with one another in a dependent and nonlinear fashion (Pereira et al. 2005; Van Jaarsveld et al., 2005). Changes in ecosystems and their services are caused by multiple interacting direct drivers (e.g., LULC change, climate change, irrigation, or alien invasive species), which in turn are controlled by indirect drivers - demographic, economic or cultural changes (MA 2003). It is clear that the ecosystem changes created consequences for current and future human well-being (Millennium Ecosystem Assessment (MA), 2005).

The necessity for environmental assessment at the landscape level has become vital to account the regional scale LULC changes. Research in land use land cover [LULC] dynamics gained significance with the realization that changes of the land surface influences climate and impact on ecosystem goods and services (Meyer and Turner 1992; Lambin et al., 2003). LULC change analysis involves measuring the areal extent of the change, with the assessment of the spatial pattern of changes (MacLeod and Congalton 1998). LULC dynamics provide insights to the intra and inter linkages of ecosystem structures with the biodiversity and human well-being. Hence sustainable land use planning for the benefit of local communities requires the knowledge of landscape dynamics (Food and Agriculture Organization, 1995; Pierce et al., 2005). Historical data plays a critical role for identifying and understanding the factors that affects natural sustainability.

Spatial data acquired since 1970's at regular intervals through space borne sensors supplemented with collateral data and field observation aid in delineating LULC changes. Linking these at a range of spatial and temporal scales to empirical models provides a comprehensive understanding of LULC dynamics (Parker et al., 1995). However, there is an urgent need for techniques to rapidly and periodically measure changes over large landscapes (Jagadeesh et al., 2009; Smith et al., 2004). The principle information of LULC changes (both temporally and spatially) with the knowledge of its impact on the landscape structure and forests are extremely important for maintaining ecosystem services and species conservation (Echeverria et al., 2006; Barlow et al., 2007).

LULC change detection using remote sensing data and GIS: Satellite remote sensing technology provide consistent measurements of landscape condition, allowing detection of both abrupt changes and slow trends over time for managing natural resources (Kennedy et al. 2009; Fraser et al., 2009). Remote Sensing (RS) data with Geographic Information System (GIS) and Global Positioning System (GPS) helps in effective measure of landscape dynamics (Ramachandra et al., 2012) in cost effective manner (Lillesand et al., 1987). These techniques have been successfully used for monitoring the Earth's surface, which are spatially continuous and highly consistent to measure spatial and temporal changes in LULC. The spatial patterns assessment over a long period has become possible due to the availability of multi-temporal coverage of remotely sensed data, which aid in an understanding of the drivers of the changes. Various parameters such as spatial (linear separation between two objects), spectral (the number and dimension of the specific wavelength interval (bands) in the electromagnetic spectrum) and temporal resolutions (how often the remote sensing system records the images of a particular area) are essential parameters in analyzing landscape dynamics. Analysed remote sensing data is combined with other data provides spatially consistent data sets with high spatio temporal details which help in detecting and monitoring the drivers for change at various scales (Ramachandra et al., 2007). This has been useful for detection and characterization of change in key resource features allowing the natural resource managers to monitor landscape dynamics over large areas, including those areas where access is difficult and facilitates extrapolation of expensive ground measurements for monitoring and management (Li et al., 2003).

Remote sensing with geoinformatics has got wide acceptance as a useful tool for planning and decision making to devise sustainable land use and environmental planning (Dewan and Yamaguchi 2009). LULC changes reflect the most significant impact on the environment due to human activities or natural forces revealed effectively by remote sensing data (Zhou et al. 2008). LULC dynamics analysis is essential to understand the magnitude and pattern of change. In addition, long-term change analysis provide insight into the drivers of change, potentially allowing for management strategies targeted toward cause rather than simply the symptoms of the cause (Kennedy et al., 2009).

Objectives: Main objective of the current study is to assess the spatial pattern of LULC changes in Uttara Kannada district, Central western Ghats in Karnataka. This involved i) land cover analysis, ii) land use analysis, iii) analysis of LULC dynamics, iv) understanding spatial patterns of LULC through spatial metrics

Measuring LULC changes: LULC changes in Uttara Kannada district is analysed using temporal remote sensing data with ancillary data and field data. The method followed for LULC analysis is represented in figure1.

Remote sensing (RS) data: Large scale land cover change detection relies on an accurate interpretation of baseline conditions and change in surface spectral properties over time. RS data used in the study are Landsat MSS (1973), TM (1989, 1999), IRS LISS-IV MX (2010), Landsat ETM$^+$ (2013) and Google Earth (http://earth.google.com). The Landsat data is cost effective, with high spatial resolution and freely downloadable from public domains like GLCF (http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp) and USGS (http://glovis.usgs.gov/). IRS P6 LISS-IV (Indian Remote Sensing Satellite, part of the Indian Space Programme) data was purchased from the National Remote Sensing Centre, Hyderabad (http://www.nrsc.gov.in). The characteristics of datasets used are summarized in Table 1.

Figure 1: Method followed in the study

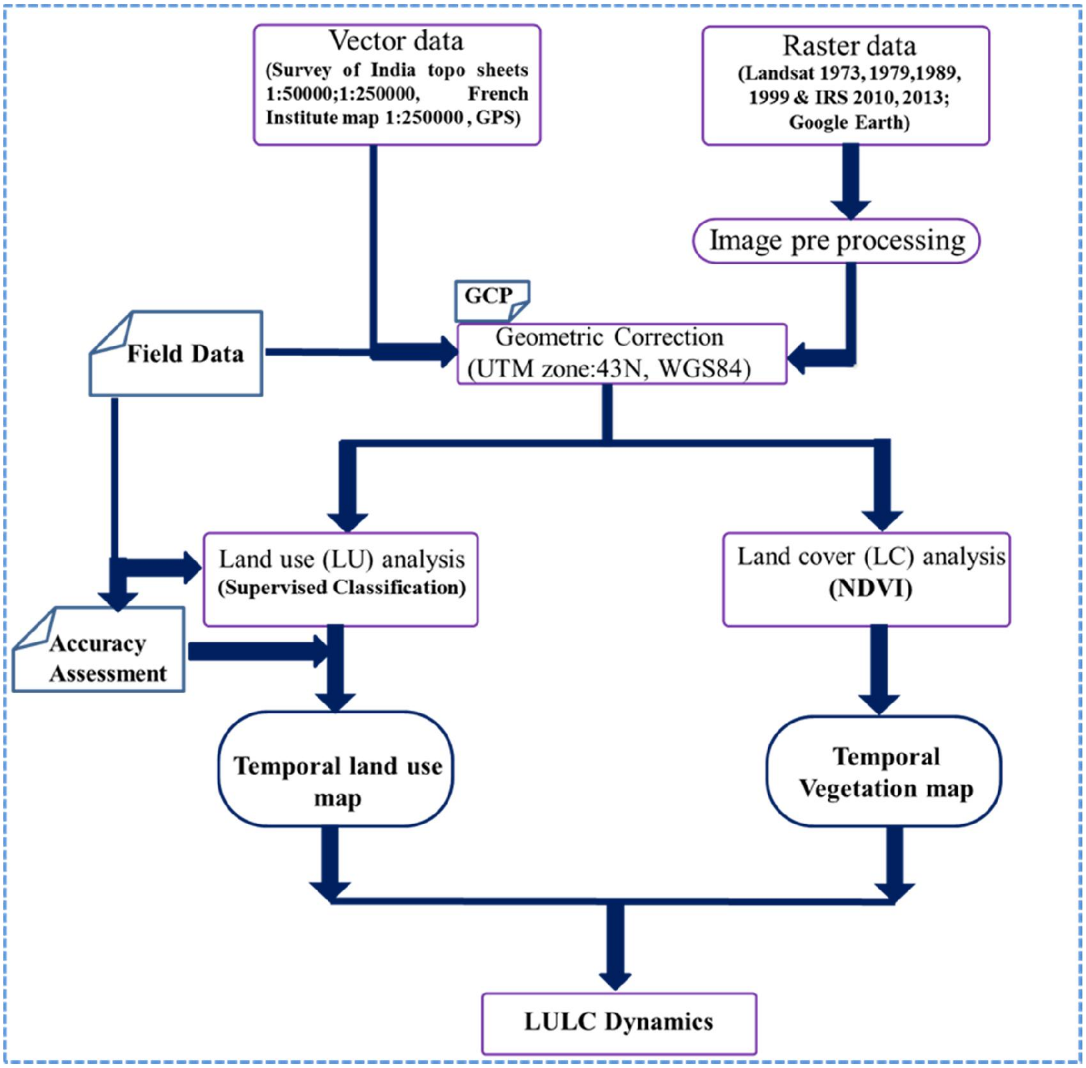


Table 1: Details of Remote sensing data

Year	Satellite	Sensor	Number of Bands	Resolution (M)
1973	Landsat	Multi Spectral Scanner (MSS)	4	57.5
1979	Landsat	Multi Spectral Scanner (MSS)	4	57.5
1989	Landsat	Thematic Mapper (TM)	7	28.5
1999	Landsat	Thematic Mapper (TM)	7	28.5
2010	IRS P6	Liss 4 Multi spectral (L4MX)	3	5
2013	Landsat	Enhanced Thematic Mapper Plus (ETM^+)	8	30

Ancillary data: Ancillary data include cadastral revenue maps (1:6000), the Survey of India (SOI) topographic maps (1:50000 and 1:250000 scales), vegetation map of South India developed by French Institute (1986) of scale 1:250000. Topographic maps provided ground control points (GCP's) to rectify remote sensing data and scanned paper maps. Vegetation map of South India (1986) of scale 1:250000 (Pascal, 1986) was digitized to identify various forest cover types and classify RS data of 1980's. Other ancillary data includes land cover maps, administration boundary data, transportation data (road network), etc. Pre-calibrated **GPS** (Global Positioning System - **Garmin GPS units)** were used for field data collection, which were used for RS data classification as well as for validation.

Method:

Pre-processing of data: Remote sensing data obtained were geo-referenced, rectified and cropped corresponding to the study area. Geo-registration of remote sensing data (Landsat data) has been done using ground control points collected from the field using pre calibrated GPS (Global Positioning System) and also from known points (such as road intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India. In the correction process numerous GCPs are located in terms of their two image coordinates; on the distorted image and in terms of their ground coordinates typically measured from a map or located in the field, in terms of UTM coordinates or latitude and longitude. The Landsat satellite 1973 images have a spatial resolution of 57.5 m x 57.5 m (nominal resolution) were resampled to 28.5m comparable to the 1989 - 2010 data which are 28.5 m x 28.5 m (nominal resolution). Landsat ETM+ bands of 2013 were corrected for the SLC-off by using image enhancement techniques, followed by nearest-neighbour interpolation. Spatio temporal change detection process involves determining the changes associated with land use and land cover properties with reference to geo-registered multi temporal remote sensing data. Vector data of the district, taluk and village boundaries, drainage network, water bodies (lakes, ponds) were digitized from the Survey of India topographic maps and cadastral maps. Population census and taluk wise village boundaries were collected from the Directorate of Census Operations, Bangalore region (http://censuskarnataka.gov.in).

Land cover analysis: Land cover analysis essentially involves delineating the region under vegetation and non-vegetation, which is done through the computation of vegetation indices NDVI (Normalized Difference Vegetation Index). Among all techniques of land cover mapping through NDVI is most widely accepted and being applied (Weismiller et al., 1977; Nelson, 1983; Ramachandra et al., 2009). NDVI is calculated by using visible Red and NIR bands which are 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). Very low values of NDVI (-0.1 and below) correspond to soil or barren areas of rock, sand, or built up. Zero indicates the water bodies. Moderate values represent low density vegetation (0.1 to 0.3), while high values indicate thick canopy vegetation (0.6 to 0.9). The outcome of NDVI (for the latest time period) was verified through field investigation and also through Google earth (http://earth.google.com). NDVI was calculated using Eq. (1)

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

Land use analysis: Land use analysis 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 validation or accuracy assessment. The land use analysis was done using supervised classification technique based on Gaussian maximum likelihood algorithm with training data (collected from field using GPS).

Maximum Likelihood algorithm has been widely applied as an appropriate and efficient classifier to extract information from remote sensing data. This approach quantitatively evaluated both the variance and covariance of the category spectral response patterns when classifying an unknown pixel of remote sensing data, assuming the distribution of data points to be Gaussian. The statistical probability of a given pixel value being a member of a particular class are computed. After evaluating the probability in each category, the pixel is assigned to the most likely class (highest probability value). **GRASS GIS *(Geographical Resources Analysis Support System)*** software is used for the analysis, which is a free and open source software having the robust support for processing both vector and raster files accessible at http://wgbis.ces.iisc.ernet.in/grass/index.php. Temporal remote sensing data have been classified through supervised classification techniques by using available multi-temporal "ground truth" information. Earlier time data were classified using the training polygon along with attribute details compiled from the historical published topographic maps, French institute vegetation maps, revenue maps, land records available from local administrative authorities, etc.

Accuracy assessments of the classified information have been done through error matrix (also referred as confusion matrix), and computation of kappa (κ) statistics and overall (producer's and user's) accuracies. This is done to evaluate the quality of the information derived from remotely sensed data considering reference pixels. **Kappa** statistic compares two or more matrices and weighs cells in error matrix according to the magnitude of misclassification (Lillisand et al., 1987; Liu et al., 2007). Producer's accuracy measures errors of omission, through correctly classified pixels in a particular category as a percentage of the total number of pixels belonging to that category in the image. User's accuracy (UA) measures errors of commission, using the number of correctly classified pixels to the total number of pixels assigned to a particular category. Accuracy assessment and kappa statistics are included in table 8. The annual change with respect to each land use category is computed by considering respective land use spatial extent at two different periods. The annual rate of change is computed using equation 2, which helps to identify magnitude of changes in the land use category (FAO, 1995; Puyravaud, 2003; Armenteras et al., 2006). This approach helps to determine change rates from "known cover" as observed forest cover by providing areas that had changed to non-forest (Tabor et al., 2010). This computation is based on the area that was classified as forest in the first date and changed to non-forest in the second date. The denominator for calculating change rates, called the "change base", is essentially the area of forest classified in the first date to the second date. The annual change is calculated as,

$$Change\,rate = \left(\frac{\ln(A_{t1}) - \ln(A_{t0})}{(t1 - t0)}\right) * 100 \quad \ldots\ldots. (2)$$

Where A_{t1} is area of lan use class in current year, A_{t0} is area of class in base year, t_1 is current year, t_0 is base year and Ln is natural logarithm. The equation will result % change of each alnd use class with negate and positive. The naegative changes indicate to rate of loss; whereas positive change rate indicate gain in land use class.

Results and Discussion:

The spatial extent of temporal vegetation computed through NDVI reveals a decline of vegetation from 97.82% (1973) to 83.44% (2013). Areas under non-vegetation have increased to 16.66% (2013) from 2.18 % (1973), due to anthropogenic activities. Table 1 lists temporal land cover and figure 2 (a, b, c, d, e and f) depicts vegetation cover during 1973, 1979, 1989, 1999, 2010 and 2013.

Table 2: land cover analysis from 1973 to 2010

Year	% vegetation	% non-vegetation
1973	97.82	2.18
1979	97.24	2.76
1989	96.13	3.87
1999	94.33	6.67
2010	89.92	10.08
2013	83.44	16.66

Temporal remote sensing data have been classified through Gaussian Maximum Likelihood Classifier [GMLC]. Landsat data available in the public domain and IRS data (2010) corresponding to the study area were classified into eleven land use categories: Evergreen forest to semi evergreen forest, moist deciduous forest, Shrub lands/grass lands, Dry deciduous forest, Acacia/Eucalyptus/ other hardwood plantations, Teak/Bamboo/ other softwood plantations, Coconut/Areca nut plantations, Built-up, Water, Crop lands, Open fields. Table 3 lists land use details during 1973 to 2013. Figure 3 depicts land uses during 1973 to 2013 while land use category wise temporal changes is given in Figure 4 (a, b, c, d, e and f). Comparative assessment of land use categories reveals the decline of vegetation cover in the district during 1973 to 2013. The reduction of area under evergreen forests from **67.73**% (1973) to **32.09**% (2013) due to anthropogenic activities involving the conversion of forest land to agricultural and horticultural activities, monoculture plantations and land releases for developmental projects. Transition of evergreen-semi evergreen forests to moist deciduous forests, and some have been converted into plantations (such as Teak, Areca nut, Acacia spp., etc.). Enhanced agricultural activities is evident from the increase of agricultural land use from **7.00 (1973) to 14.13 % (2013)** and the area under human habitations have increased during the last four decades, evident from the increase of built-up area from **0.38%** (1973) to **3.07%** (2013). Unplanned developmental activities coupled with the enhanced agriculture and horticultural activities have aided as prime drivers of deforestation, leading to the irreversible loss of forest cover with the reduction of ecosystem goods and services. The increase in plantation of exotic species has led to the removal of forest cover and also extinctions of species. *Acacia auriculiformis, Casuarina equisetifolia, Eucalyptus spp., and Tectona grandis* have been planted widely in the district. Acacia and Teak plantations constitute 12.04% and 6.60% respectively in the district. The dry deciduous forest cover is very less (0.96%) and is found mainly in the north eastern part of the district in Mundgod taluk and partly Haliyal taluk.

Table 3: land use variation from 1973 to 2013

Year / Category	1973		1979		1989		1999		2010		2013		Loss / Gain in area (1973-2013)
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	(Ha)
Built-up	3886	**0.38**	9738	0.95	12,982	1.26	21,635	2.10	28,491	2.77	31589	**3.07**	27703
Water	7,681	0.75	18527	1.80	16,604	1.61	32,983	3.21	26,119	2.54	28113	2.73	20432
Crop land	71,990	**7.00**	103163	10.02	121,167	11.77	138,458	13.45	148,187	14.40	145395	14.13	**73405**
Open fields	14071	1.37	15988	1.55	34,783	3.38	21,945	2.13	30,812	2.99	37660	3.66	23589
Moist deciduous forest	**95,357**	**9.27**	**102967**	**10.01**	**143,849**	**13.98**	**179,075**	**17.40**	**166,266**	**16.15**	**161,996**	**15.74**	66639
Evergreen to semi evergreen	**696,978**	**67.73**	**589762**	**57.31**	**531,872**	**51.68**	**423,062**	**41.11**	**367,064**	**35.66**	**330,204**	**32.08**	**-366774**
Scrub/grass	38,109	3.70	58936	5.73	44,123	4.29	47,366	4.60	35,158	3.42	40402	3.93	2293
Acacia/Eucalyptus/ hardwood plantations	40,905	**3.97**	50321	4.89	55,694	5.41	73,977	7.19	119,717	11.63	122927	**11.94**	82022
Teak/ Bamboo/ softwood plantations	13997	**1.36**	20896	2.03	21,937	2.13	38,588	3.75	44,794	4.35	67111	**6.52**	53114
Coconut/ Areca nut / Cashew nut plantations	20,702	**2.01**	29675	2.88	32,227	3.13	43,623	4.24	53,646	5.21	53,993	**5.25**	**33291**
Dry deciduous forest	25,410	2.47	29113	2.83	13,848	1.35	8374	0.81	9008	0.88	9873	0.96	-15537
Total	1029086												

The areas of each category were also compared with available administrative reports, statistical department data and forest division annual reports. Table 4 lists the accuracy of classifications, verified using field data and Google earth data. The collected field data is separated with respect to each category, 60% used as a training set and 40% used for verification. Accuracy of the classification ranges from 87 to 93% with more consistent results. Cautious steps were taken to make sure separate data sets used for training and validation. This is essential because there will be a chance of getting greater accuracy of classification but lesser ground consistent when same data is used both for classification and confirmation.

Table 4: Accuracy assessment of the study

Year	*Accuracy*	*Built-up*	*Water*	*Crop land*	*Open land*	*Moist deciduous*	*Ever green to semi*	*Scrub*	*Acacia*	*Teak*	*Coco nut*	*Dry deciduous*
1973	**PA**	67.61	90.73	83.14	86.54	82.36	90.24	58.92	72.39	74.85	50.16	92.27
	UA	66.69	89.94	79.26	86.42	81.45	89.82	57.52	71.58	78.18	66.02	91.84
1979	**PA**	68.66	92.00	95.45	81.73	68.16	93.00	64.41	65.58	47.18	38.57	46.47
	UA	90.00	85.40	74.30	78.56	85.05	89.15	90.78	93.43	94.84	94.67	74.10
1989	**PA**	98.28	99.62	95.83	91.58	88.76	94.59	92.28	97.44	84.41	38.83	80.89
	UA	77.6	95.53	87.09	93.84	97	97.84	98.16	74.33	59.18	73.75	70.07
1999	**PA**	79.88	98.14	98.62	76.22	88.72	98.02	85.61	89.93	81.63	88.22	88.86
	UA	88.4	97.67	98.35	83.32	95.9	96.68	84.79	85.81	82.4	89	31.5
2010	**PA**	60.34	99.77	97.49	89.81	87.92	93.91	93.24	92.53	78.68	89.92	86.78
	UA	94.14	99.56	90.11	89.13	85.54	96.3	85.7	90.98	91.1	80.02	86.85
2013	**PA**	92.53	95.32	80.00	86.25	92.84	96.53	67.71	69.08	78.68	91.03	97.49
	UA	23.87	96.80	98.10	68.05	88.50	98.90	13.59	94.10	91.10	97.70	90.11

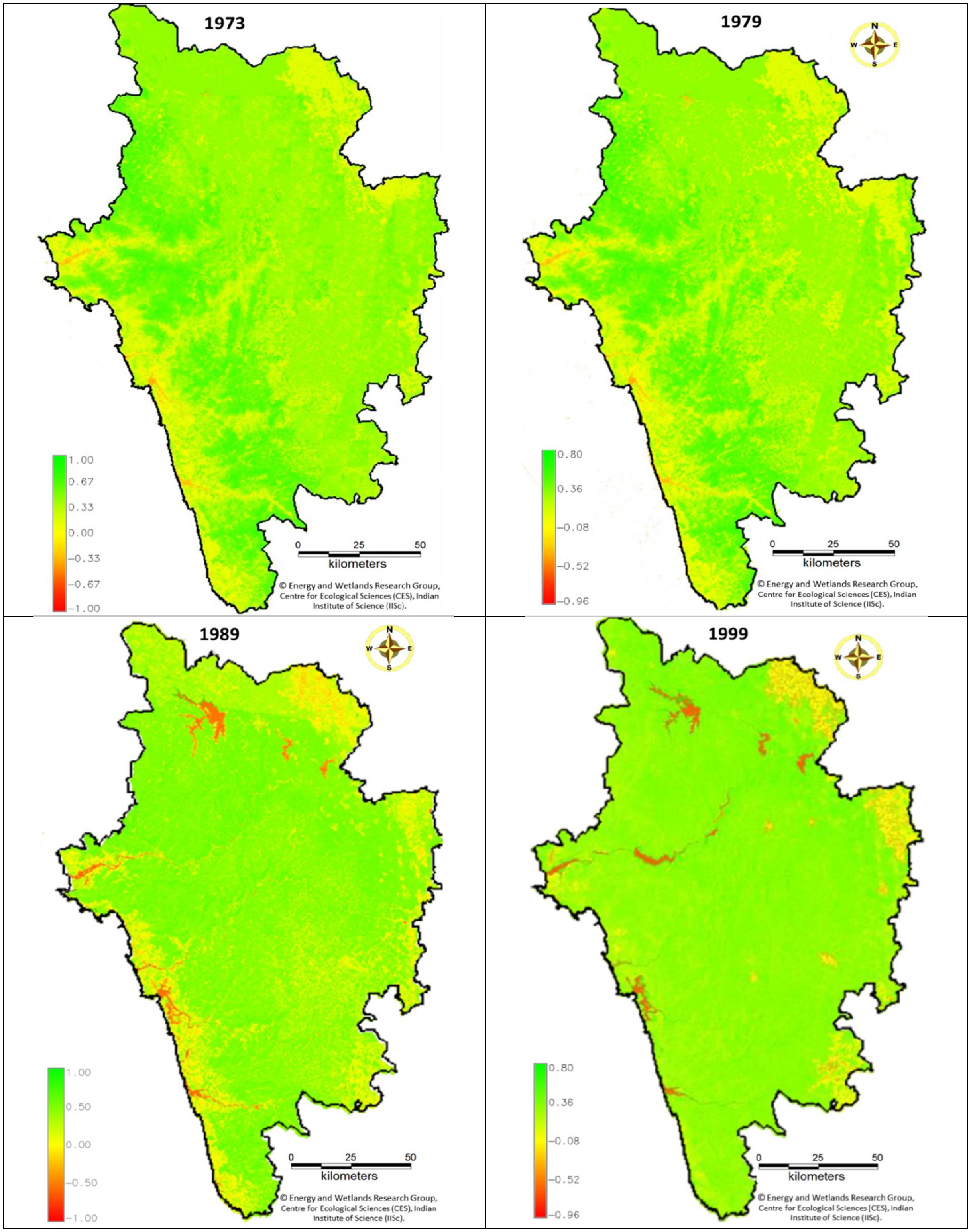
*** PA – Producer's Accuracy; UA – User's Accuracy**

Year	*Overall Accuracy*	*Kappa*
1973	82.52	0.81
1979	84.29	0.81
1989	92.22	0.89
1999	90.71	0.87
2010	91.51	0.89
2013	91.98	0.90

Ecologically fragile swampy areas are being encroached and converted to plantations of *Areca catechu, Cocos nucifera*. Land use changes in this region is mainly due to extensive clearing of natural vegetation (deforestation) for agriculture expansions in the most productive lands, the abandonment of marginal lands and commercial plantations. Construction of new subdivision roads and buildings, widening of highways increased dramatically during 1990's. The construction of roads and houses in valley slopes, have also enhanced the episodes of landslides in the district. More recently, the impetus to industrialization has encouraged the concentration of human populations at taluks such as Karwar, Bhatkal, Honnavara, Sirsi.

Figure 2(a, b, c, d, e, f) Land cover analysis from 1973 to 2013

(a) 1973 (b) 1979 (c) 1989 (d) 1999 (e) 2010 (f) 2013



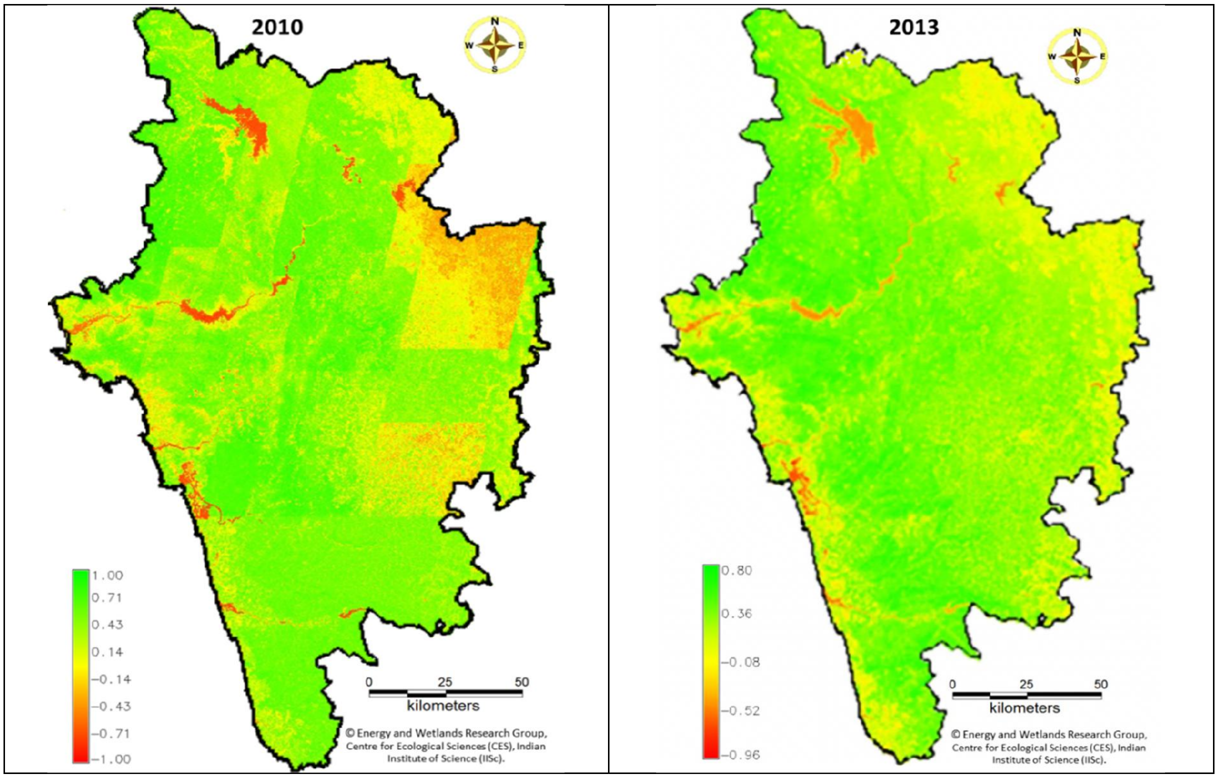
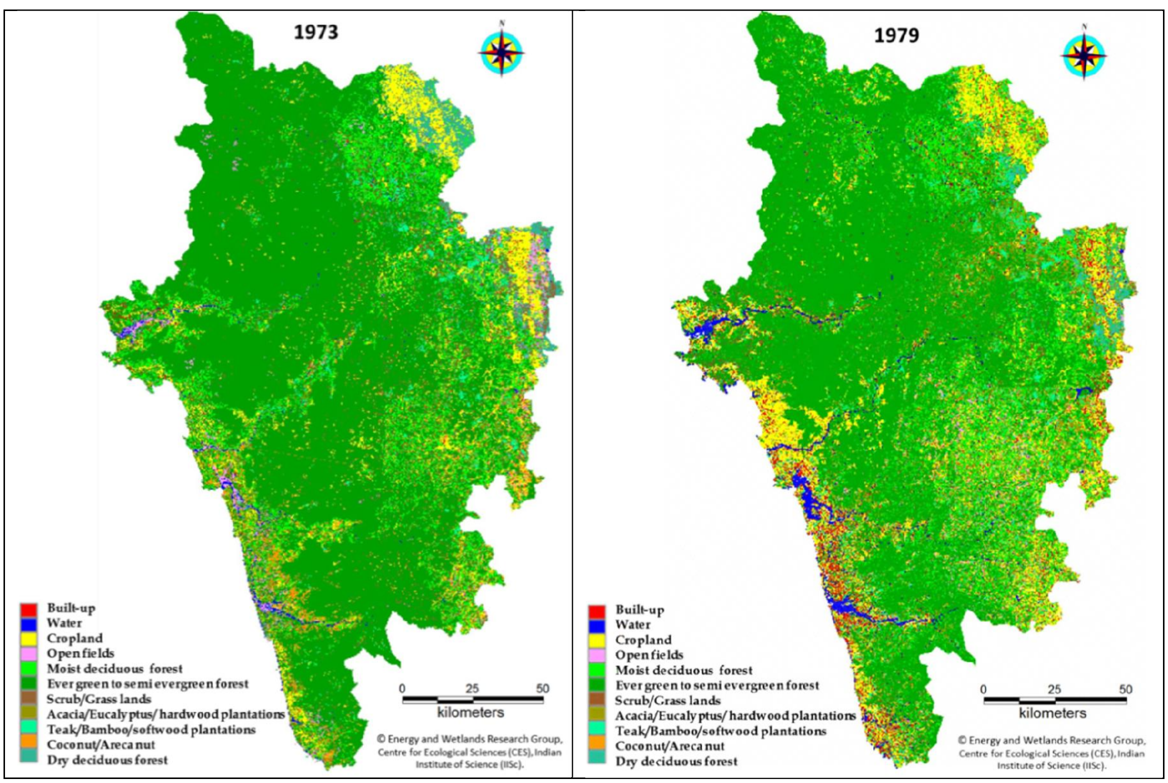
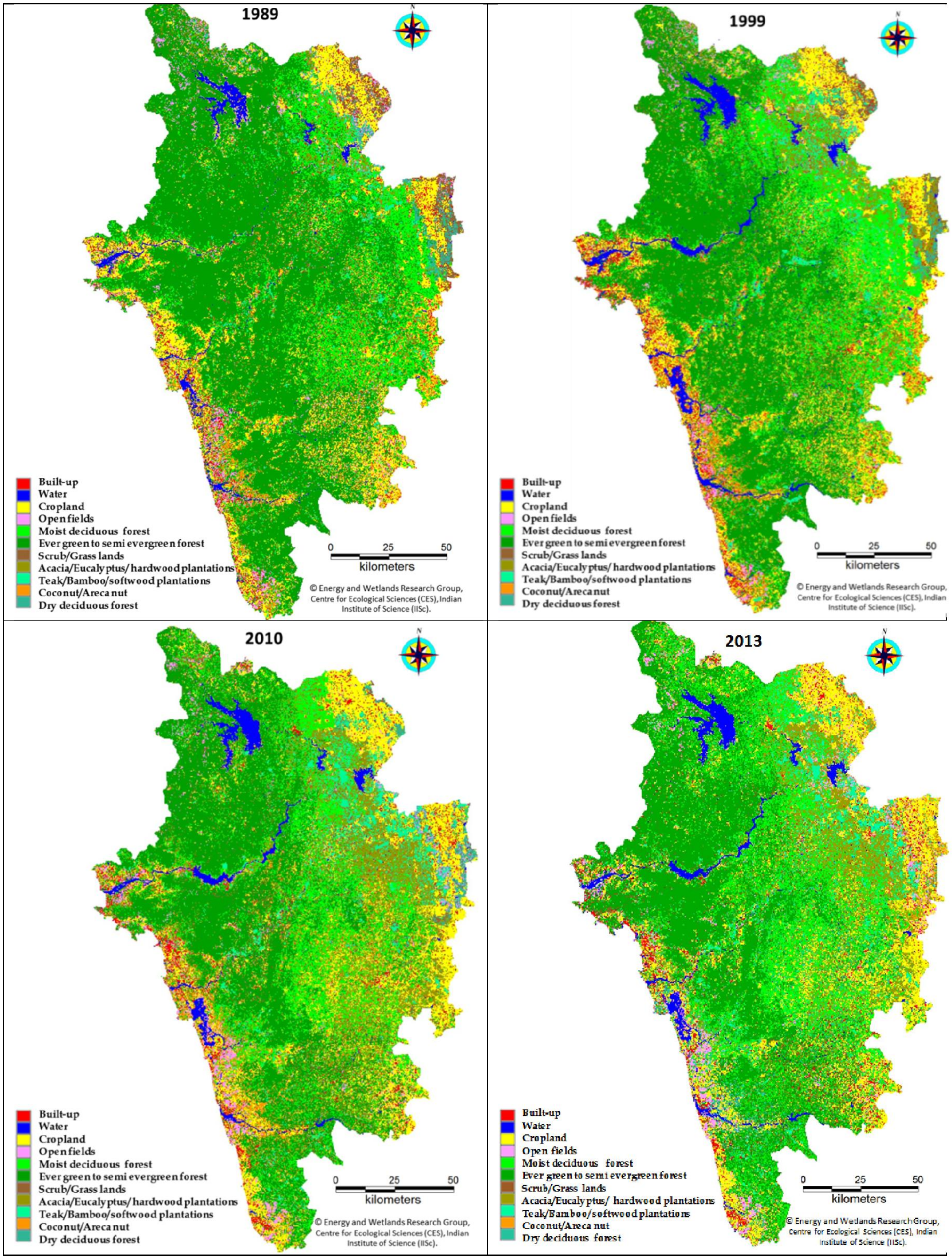


Figure 3: Uttara Kannada district land use change from 1973 to 2013
(a) 1973 (b) 1979 (c) 1989 (d) 1999 (e) 2010 (f) 2013




1989
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
Coconut/Areca nut
Dry deciduous forest
0 25 50
kilometers
© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
1999
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
Coconut/Areca nut
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© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
2010
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
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© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
2013
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
Coconut/Areca nut
Dry deciduous forest
0 25 50
kilometers
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Figure 4: Spatio temporal land use dynamics

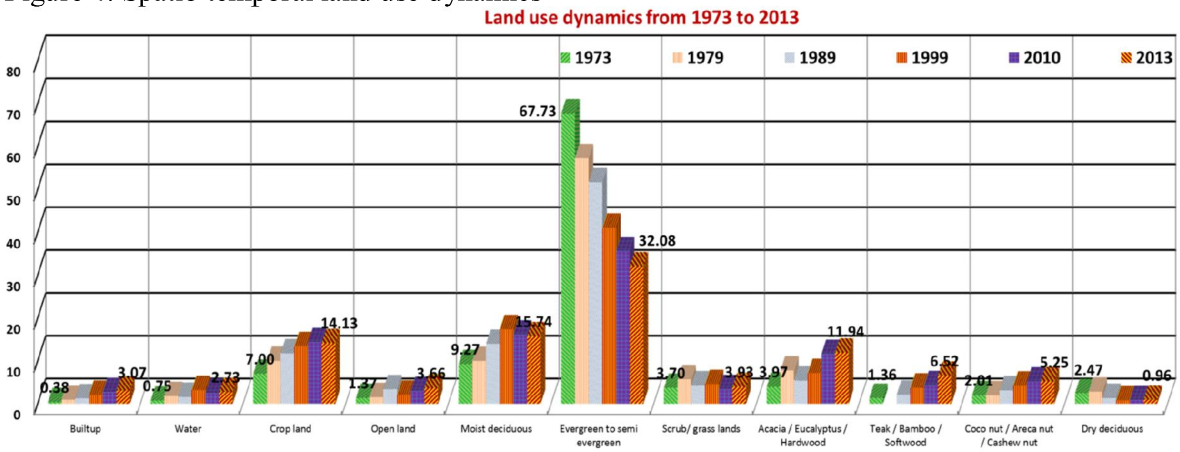


Figure 5: temporal variation of land use change rate from 1973 to 2013

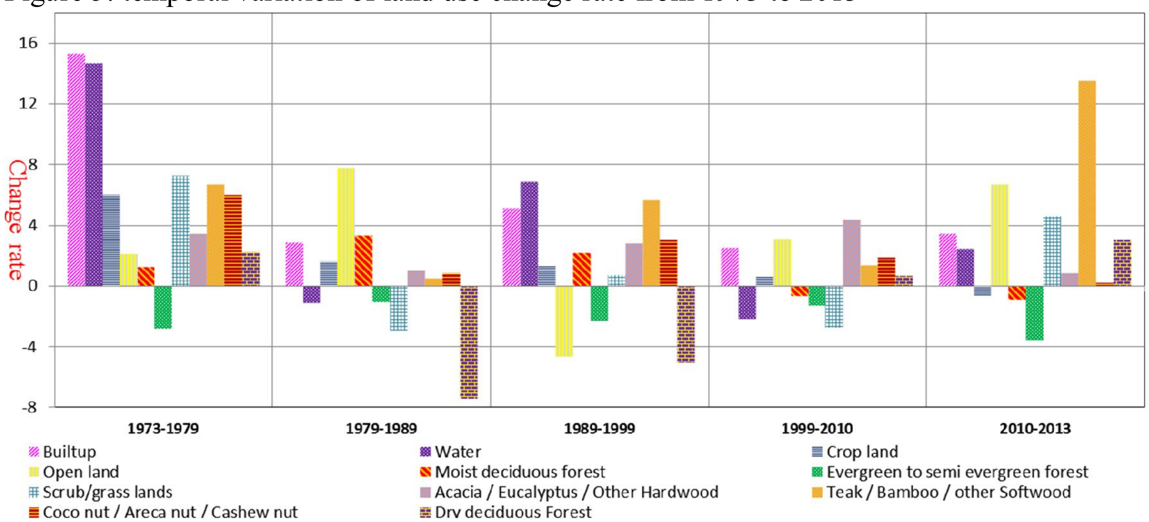
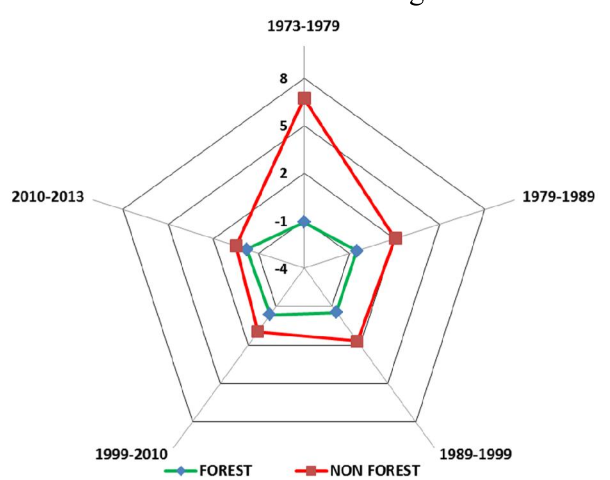


Figure 6: Changes in forest and non-forest land use categories from 1973 to 2013



Category-wise rate of **land use changes were** computed to identify the categories which have undergone severe transformation. The annual rate of change at temporal scale provides landscape modification with respect to each period and category wise changes are listed in Table 5 and depicted in Figure 5. Higher changes are noticed during 1973-79 followed by 2010 to 2013. The built-up area shows as positive increase 15.31% y^{-1}(per year). The evergreen forest shows change of -2.78%y^{-1} (1973-1979) and -3.53%y^{-1} (2010-2013). Forest plantations and horticulture show an increase during 1973 to 2013, indicating market role in land conversions. The abrupt land use changes are due to large-scale developmental activities, change in agriculture practices and increase in population.

Table 5: land use change rate from 1973 to 2013

Rate of Change in land use categories (%)					
Category	**Time period**				
	1973-1979	**1979-1989**	**1989-1999**	**1999-2010**	**2010-2013**
Built-up	**15.31**	**2.88**	**5.11**	**2.50**	**3.44**
Water	14.67	-1.10	6.86	-2.12	2.45
Crop land	6.00	1.61	1.33	0.62	-0.63
Open spaces	2.13	7.77	-4.61	3.09	6.69
Moist deciduous forest	1.28	3.34	2.19	-0.67	-0.87
Evergreen to semi evergreen forest	**-2.78**	**-1.03**	**-2.29**	**-1.29**	**-3.53**
Scrub/grass lands	7.27	-2.89	0.71	-2.71	4.63
Acacia / Eucalyptus / Other Hardwood	3.45	1.01	2.84	4.38	0.88
Teak / Bamboo / other Softwood	6.68	0.49	5.65	1.36	13.48
Coconut / Areca nut / Cashew nut	6.00	0.82	3.03	1.88	0.21
Dry deciduous Forest	2.27	-7.43	-5.03	0.66	3.06

Changes in forest (evergreen–semi evergreen, moist deciduous, dry deciduous, scrub forest) and non-forest (built-up, crop land, open spaces, plantations) land uses for different time period is computed to understand the change dynamics. Table 6 lists category wise annual changes for different time period and the same is depicted in Figure 6. Non-forest regions such as agriculture, built environments show an increasing trend in each time period, evident from an annual increase of 6.72% (during 1973 to1979), 2.07% (during 1979to 1989), 1.72 % (during 1989-1999), 0.95 (during 1999-2010) and 0.51% (during 2010-2013). In contrast to this, area under forests show a declining trend of -1.11% (1973 to 1979), -0.49% (1979 to 1989) and -0.21% (2010-2013).

Table 6: forest and non-forest land use change rate from 1973 to 2013

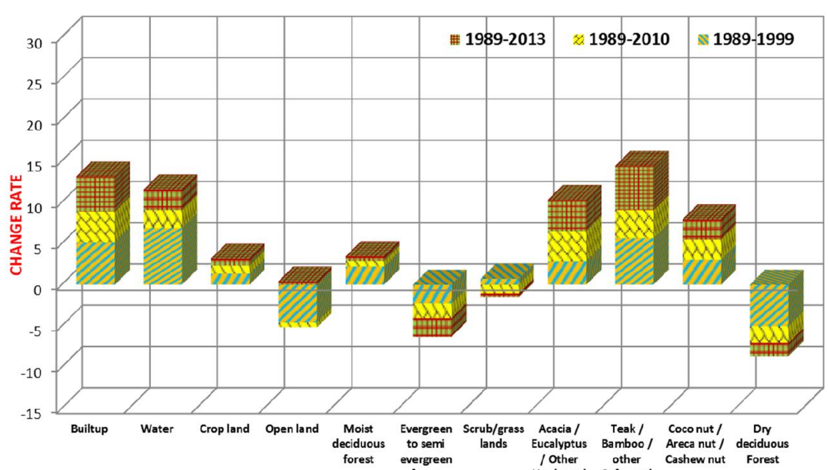
Land use category	1973-1979	1979-1989	1989-1999	1999-2010	2010-2013
FOREST	-1.11	-0.49	-0.52	-0.34	-0.21
NON-FOREST	6.72	2.07	1.72	0.95	0.51

Forest (Conservation) Act, 1980 and amendment 1988, National Board for Wildlife and State Boards for Wildlife for identification of future protected areas helped in effective management of forests in the region. The regulatory laws and protection measures were tried through formalization of national parks, wildlife sanctuaries, conservation reserves and community reserves. This approach helped to regenerate regions of disturbed forests. However, unplanned developmental activities such as construction of series of dams and encroachment of forests for non-forestry purposes led to the deforestation of forests. Compensatory afforestation has not yielded the desired results due to monoculture plantations and less prominence to the regeneration of forest patches through protection or appropriate conservation measures. Considering 1989 as base year, change analysis reveal declining trend of forests (Table 7, Figure 7). The evergreen forest cover has decline at -2.29% (1989-1999), -1.77% (1989-2010) and -2.27% (1989-2013). Due to infrastructure projects (roads, rail network), dams, project Seabird and Kaiga nuclear plant, built-up category show an increase of 5.11%, 3.74%, 4.23% respectively. Village forests were created to meet the needs of people and discourage exploitation from forests. Due to degradation of village forests, fuel wood for domestic purposes is being collected from forests.

Table 7: Computed change rate of land use by considering 1989 as a base year

Category	Time period (1989 as a base year)		
	1989-1999	1989-2010	1989-2013
Built-up	5.11	3.74	4.23
Water	6.86	2.16	2.51
Crop land	1.33	0.96	0.87
Open land	-4.61	-0.58	0.38
Moist deciduous forest	2.19	0.69	0.57
Evergreen to semi evergreen forest	-2.29	-1.77	-2.27
Scrub/grass lands	0.71	-1.08	-0.42
Acacia / Eucalyptus / Other Hardwood	2.84	3.64	3.77
Teak / Bamboo / Other Softwood	5.65	3.40	5.32
Coco nut / Areca nut / Cashew nut	3.03	2.43	2.46
Dry deciduous Forest	-5.03	-2.05	-1.61

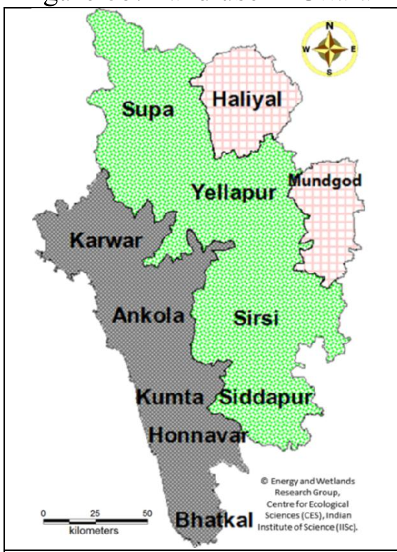
Figure 7: Changes in forest and non-forest land use classes from 1989 to 2013 (1989 as a base)



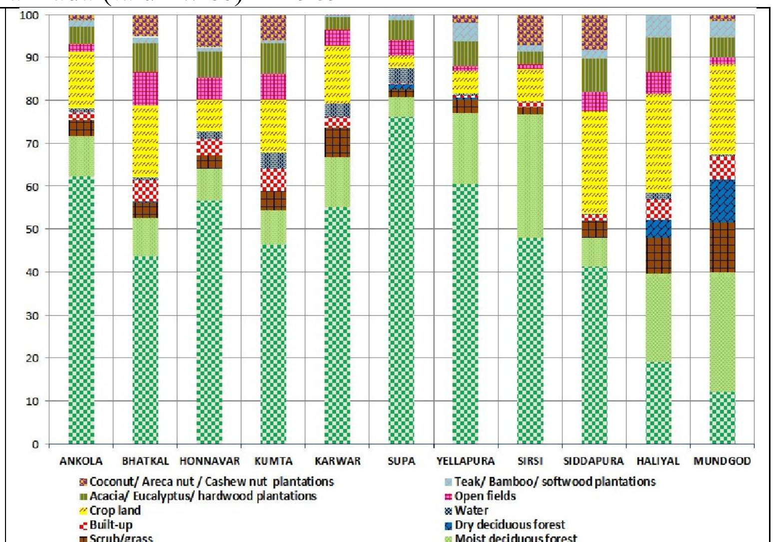
Land use analysis at taluk levels:

Uttara Kannada is a unique landscape of Karnataka state which supporting several ecosystems, namely forest, marine, estuarine, riverine and a variety of land based ones. The district comprises of 11 taluks, which can be grouped in three distinct zones based on its elevation and agro climatic condition (Figure 8). Karwar, Ankola, Kumta, Honnavar, Bhatkal taluks are located in coastal zone. These taluks with high density of population have higher degree of economic development. Mountainous Sahyadri zone with dense evergreen and semi evergreen forest cover consist of Supa, Yellapur, Sirsi, Siddapur taluks. Haliyal, Mundgod taluks are in plains zone connecting Deccan plateau. Plains mainly consists of agriculture and also dominated by plantation activities. Taluk wise land use analysis is carried out and is given in Table 8. Figure 9 (a to k) provides taluk-wise land uses of the district.

Figure 8a: Uttara Kannada district with taluks and agro-climatic zones
Figure 8b: Land use in Uttara Kannada (taluk wise) in 1989



8a: Taluk



8b: Land use, taluk wise during 1989

Ankola: The Ankola taluk is most dominated by semi evergreen to moist deciduous forest cover from east to west. There are pockets of evergreen forests in the central part of Ankola. Towards the coastal side there is a mainly mango, cashew nut, coconut and areca nut plantations. Gangavalli river supports valuable plantations of forest department. The total population of taluk is 101,549 and density is 109 persons/km^2. The most significant changes are noticeable in categories of evergreen forest cover loss and increase in coconut/areca nut/ Cashew plantations from 1973 to 2013. The Ankola town is experiencing more urbanisation after 2005 because of Project Sea Bird (Karwar), medium scale industry, small scale Industrial estate (comprises of 357 industries) and other developmental activities in and around taluks. The taluk is well connected by bus and train. Konkan railways, National Highway 17 (NH-17, now NH-66) are passes through Ankola from Goa to Udupi. East Direction is connected to Hubli by National Highway 63 (NH-63). Decline of evergreen forests from 75.66 (1973) to 55.43 % (2013) is noticed in the taluk. The land use analysis

(Figure 9 (a) & table 8(a)) for year 2013 reflects 4.26% of area under built-up, 8.87% area under crop lands and 55.43% area is under evergreen forest cover.

Table 8 (a): Land use of Ankola

Taluk: ANKOLA				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**101.62**	**0.11**	**3956.02**	**4.26**
Water	465.05	0.5	1179.40	1.28
Crop land	4246.87	4.57	8237.76	8.87
Open fields	757.29	0.82	2519.86	2.71
Moist deciduous forest	9284.19	10	9106.97	9.81
Evergreen to semi evergreen forest	**70272.39**	**75.66**	**51459.60**	**55.43**
Scrub/grass	2481.88	2.67	4553.17	4.9
Acacia/ Eucalyptus/ hardwood plantations	2879.36	3.1	4389.08	4.73
Teak/ Bamboo/ softwood plantations	1286.78	1.39	2753.12	2.97
Coconut/ Areca nut / Cashew nut plantations	897.37	0.97	4653.46	5.01
Dry deciduous forest	204.03	0.22	23.62	0.03
Total	92876.80			

Bhatkal: Bhatkal taluk is having highest population density (426 persons/km^2, 149,338) in the district and it is a port town in Uttara Kannada district. The town has renowned history from 8th century by Cholas considered as one of territory for the kingdom. Bhatkal town is located at NH-17 running between Mumbai and Kochi and also connected by Konkan Railway line running between Mangalore to Mumbai. The region is having rich lateritic belt and representing 7.43% open space. This region is dominated by evergreen to semi evergreen forest and moist deciduous forests. The land use analysis (Figure 9 (b) and table 8 (b)) shows built-up has increased from 0.22% to 5.1% followed by 7.91% to 23.5% of crop lands. Scrub type forest cover has increased from 2.28% to 7.36%. The loss of evergreen forests from 61.39% to 30.38% indicates the need for forest conservation in Western Ghats.

Table 8 (b): Land use of Bhatkal

Taluk: BHATKAL				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**76.048**	**0.21**	**1831.352**	**5.09**
Water	3264.884	9.07	310.947	0.86
Crop land	2737.765	7.61	8160.149	22.68
Open fields	796.648	2.21	2668.985	7.42
Moist deciduous forest	2313.519	6.43	4808.104	13.36
Evergreen to semi evergreen forest	**22,090.55**	**61.39**	**10933.353**	**30.38**
Scrub/grass	819.803	2.28	2648.946	7.36
Acacia/ Eucalyptus/ hardwood plantations	1139.64	3.17	1014.815	2.82
Teak/ Bamboo/ softwood plantations	782.83	2.18	1161.296	3.23
Coconut/ Areca nut / Cashew nut plantations	1905.865	5.30	2448.016	6.80
Dry deciduous forest	58.748	0.16	0.81	0.00
Total	35986.30			

Honnavar: Honnavar taluk is prime coastal taluk of the district, a port town lies on the coast of the Arabian Sea and on the banks of the river Sharavati, forming a transcendent estuary. The taluk is well connected with two national highways (NH-17; NH-206) and renowned for major economic activities. The forest type of Honnavar changes from semi-evergreen to evergreen. The coastal strip is highly denuded due to cash crop activities. The forests in the northeastern corner comprises of palms. The evergreen forest of Gerusoppa comprises of canes. The land use analysis (Figure 9 (c) & table 8 (c)) highlight the loss of evergreen forest cover from 70.63 (1973) to 35.71% (201. The crop land covers 14.23% (2013) and intensified coconut/ areca nut plantation activities (14.41%) can be observed. Especially the estuarine regions are more prone to the coconut plantation activities. The Honnavar forest landscape is one of relic rain forests of the central Western Ghats, where the high endemic vegetation still exists. The loss of evergreen forest in this region reflects continued pressure on forests and alteration of landscapes, leading to an enhanced water-run off and decrease in watershed value of forests.

Table 8 (c): Land use of Honnavar

Taluk: HONNAVAR				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**49.06**	**0.07**	**2753.94**	**3.68**
Water	2060.54	2.20	2186.91	2.92
Crop land	2575.49	3.43	10660.70	14.23
Open fields	1697.86	2.26	3478.47	4.64
Moist deciduous forest	4748.68	6.33	8290.53	10.96
Evergreen to semi evergreen forest	**52955.86**	**70.63**	**26751.52**	**35.71**
Scrub/grass	1448.69	1.93	4572.75	6.10
Acacia/ Eucalyptus/ hardwood plantations	2902.22	3.87	3026.16	4.04
Teak/ Bamboo/ softwood plantations	505.65	0.67	2473.29	3.30
Coconut/ Areca nut / Cashew nut plantations	**5936.80**	**7.92**	**10793.78**	**14.41**
Dry deciduous forest	100.55	0.13	0.63	0.00
Total	74981.38			

Karwar: Karwar is the administrative headquarters of Uttara Kannada district. The forest type of region changes from semi-evergreen to evergreen. The upper slopes lower Kali river valleys consists of patches of evergreen forests and large number of canes. Land use analysis (Figure 9 (d) & table 8(d)) show that 3.48% area is under built-up, 7.06% area is under agriculture. Anthropogenic pressure and infrastructure development has led to loss of evergreen forests from 72.26% to 59.70% (1973-2013). This taluk has witnessed many developmental activities like Project seabird, Kodasalli dam, Kaiga nuclear power project. The unplanned construction boom has physically altered the appearance and ambience of the forests as well its peripheral neighbourhoods of Karwar taluk. An industrial estate was established in 1991 at Shirwad in Karwar taluk of 35 acres land. Exotic plantations of 2.78% were developed to cater the fuel wood and other requirements.

Table 8 (d): Land use analysis of Karwar

Taluk: KARWAR				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**1159.21**	**1.56**	**2573.20**	**3.48**
Water	1077.29	1.45	3835.23	5.19
Crop land	3976.58	5.37	5221.11	7.06
Open fields	1629.74	2.20	3042.27	4.11
Moist deciduous forest	**8921.41**	**12.04**	**4167.73**	**5.43**
Evergreen to semi evergreen forest	**53552.78**	**72.26**	**44153.39**	**59.70**
Scrub/grass	1523.03	2.06	5664.30	7.66
Acacia/ Eucalyptus/ hardwood plantations	1658.00	2.24	2053.93	2.78
Teak/ Bamboo/ softwood plantations	380.96	0.51	1453.17	1.96
Coconut/ Areca nut / Cashew nut plantations	56.06	0.08	1933.72	2.61
Dry deciduous forest	175.14	0.24	12.38	0.02
Total	74110.428			

Kumta: Kumta is coastal taluk at the Arabian Sea coast in the district and adjacent to the vast western ghats. The major river Aghanashini and its estuary referred as one of the major source of income of the taluk with valuable fish and bivalves. The forest type changes from semi-evergreen to evergreen. Land use analysis (Figure 9 (e) & table 8(e)) shows area under built-up is increased to 3.75% (2013) from 0.21% (1973), and 11.58% area under agriculture. The ever green forest has declined from 62.29% (1973) to 29.43% (2013) with the increase in agriculture area 11.59% (2013). Coconut/ Areca nut / Cashew plantations cover 9.65%.

Table 8 (e): Land use analysis of Kumta

Taluk: KUMTA				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**122.20**	**0.21**	**2199.09**	**3.75**
Water	1248.05	2.13	4101.50	6.99
Crop land	3500.97	5.97	6795.96	11.58
Open fields	2130.84	3.63	4702.98	8.01
Moist deciduous forest	**5494.05**	**9.36**	**9066.18**	**15.45**
Evergreen to semi evergreen forest	**36901.63**	**62.89**	**17246.39**	**29.38**
Scrub/grass	1507.11	2.57	1782.24	3.04
Acacia/ Eucalyptus/ hardwood plantations	3067.49	5.23	3716.90	6.33
Teak/ Bamboo/ softwood plantations	981.25	1.67	2790.36	4.75
Coconut/ Areca nut / Cashew nut plantations	3396.66	5.79	6280.86	10.70
Dry deciduous forest	329.27	0.56	11.08	0.02
Total	58693.54			

Siddapur: Siddapur taluk is located in the core of Western Ghats with lush greenery, hills and Areca nut gardens developed in the valleys but the eastern part is drier. Agriculture based economy exists in the taluk. The forest cover type is dense evergreen to semi-evergreen. There are many patches of evergreen forests called “Kans” in this taluk, which are mostly confined to the west, near Dodmane and Malemane ghats. ‘Kan’ forests in the Western Ghats of Karnataka are relic forest patches protected by people since historic times due to their sacred importance and hence these remain are important for conservation of evergreen forests species in the Western Ghats (Chandran and Gadgil 1993). The land use (Figure 9 (f) & table 8 (f)) of the region shows built-up area has increased from 0.24% to 7.02% and crop lands have increased from 4.17% to 19.08% at the loss of thick evergreen forests from 1973 to 2013. The evergreen forest cover has lost from 71.77% (1973) to 23.68 (2013)% due to anthropogenic activities. Areca/ Coconut plantations have increased by 7.94%. Encroachment of forest land is a serious threat in Sirsi, Siddapur regions. The forests serve an important ecological function of holding the rain water and delayed release during lean seasons into the stream systems. Ignoring this fact, high endemic and swampy regions are being converted as areca nut gardens due to continuous water availability. This is posing serious threat to natural vegetation cover. In addition to this, intensified acacia/teak plantations were taken up, impacting local biodiversity, hydrology and ecology.

Table 8 (f): Land use analysis of Siddapur

Taluk: SIDDAPUR				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**210.76**	**0.24**	**6053.65**	**7.02**
Water	69.32	0.08	311.01	0.36
Crop land	3592.98	4.17	16451.14	19.08
Open fields	536.48	0.62	2458.36	2.79
Moist deciduous forest	**11098.23**	**12.87**	**16594.68**	**19.25**
Evergreen to semi evergreen forest	**61605.68**	**71.42**	**20411.27**	**23.68**
Scrub/grass	4174.24	4.84	5419.43	6.29
Acacia/ Eucalyptus/ hardwood plantations	940.66	1.09	9355.40	10.85
Teak/ Bamboo/ softwood plantations	923.41	1.07	2122.45	2.46
Coconut/ Areca nut / Cashew nut plantations	3033.41	3.52	6845.40	7.94
Dry deciduous forest	71.20	0.08	233.34	0.27
Total	86256.37			

Sirsi: Sirsi taluk is a major trading center (economic zone) of the district surrounded with thick green forest, many water falls. Areca nut (Adike) or (Betel nut) is the primary horticulture crop grown in villages is exported even to abroad providing plenty of business opportunities. The major food crop is paddy and also the region is renowned for many other spices like cardamom, pepper, betel leaves, vanilla, etc. The forests of Sirsi taluk are primarily semi-evergreen and evergreen types. Land use (Figure 9 (g) & table 8 (g)) of the taluk represents 1.85% of built-up area, 21.21% of crop land. Evergreen forests have declined from 64.89% (1973) to 16.78% (2013). The increase of areca nut plantations (8.58%) and Acacia/Eucalyptus plantations (15.39%) are responsible for land use changes. Forest based small scale enterprises are encouraged widely in Sirsi, Siddapur taluks which incorporate wide range of activities; the collection of forest products such as fruits, leaves, gums, resins and their processing by hand or simple machinery. Their products have marketing from household consumption and trading to the international. But recent trend of this activities which are practicing at unsustainable way are showing adverse effects on forests. With the rapid demographic and economic changes, collection practices have changed leading to unsustainable exploitation. Constructions of new roads inside forests to facilitate movement of vehicles and exploitation are further degrading forests.

Table 8 (g): Land use analysis of Sirsi

Taluk: SIRSI				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	293.36	0.22	2441.33	1.85
Water	56.99	0.04	283.21	0.22
Crop land	**8967.9**	**6.81**	**27,938.78**	**21.21**
Open fields	1128.92	0.86	719.66	0.55
Moist deciduous forest	16,588.07	12.6	36,994.83	28.09
Evergreen to semi evergreen forest	**85,416.10**	**64.89**	**22,103.98**	**16.78**
Scrub/grass	8862.09	6.73	2186.19	1.66
Acacia/ Eucalyptus/ hardwood plantations	2495.88	1.9	20,265.40	15.39
Teak/ Bamboo/ softwood plantations	1928.35	1.47	7161.23	5.44
Coconut/ Areca nut / Cashew nut plantations	**5451.07**	**4.14**	**11,303.81**	**8.58**
Dry deciduous forest	433.51	0.33	308.25	0.23
Total	131706.7			

Supa: Supa also known as Joida is characterized by highest forest cover in the district with least population. Evergreen patches are also found in the valleys of Kali river. Supa Dam constructed across Kali river has submerged ever green forests and a major town Joida. Relocation of Supa dam evacuees was done at Ramanagar near Londa on the border Uttara Kannada district. The region was under reserved forest, which was taken over for resettlement.

Table 8 (h): Land use analysis of Supa

Taluk: SUPA				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	129.75	0.07	587.56	0.31
Water	554.27	0.29	11,556.24	6.11
Crop land	1974.02	1.04	7598.36	4.02
Open fields	900.25	0.48	5767.28	3.05
Moist deciduous forest	**4917.64**	**2.60**	**32,017.18**	**16.92**
Evergreen to semi evergreen forest	**177,041.77**	**93.56**	**110,723.18**	**58.51**
Scrub/grass	1310.3	0.69	6217.6	3.29
Acacia/ Eucalyptus/ hardwood plantations	728.25	0.38	7703.68	4.07
Teak/ Bamboo/ softwood plantations	996.76	0.53	5368.56	2.84
Coconut/ Areca nut / Cashew nut plantations	0	0.00	725.83	0.38
Dry deciduous forest	671.79	0.36	960.01	0.51
Total	189224.8			

The land use analysis (Figure 9 (h) & table 8(h)) shows transformation of high forested landscape with the decline of evergreen forest cover from 93.56% (1973) to 58.79% (2013). Drivers of these changes are construction of series of dams on Kali river basin and also consequent land requirement for human settlements. Soft wood extractions to support forest based industries is also affecting the vegetation cover. Mechanized sand mining with at least 400 trucks sand haul every day in the Kali valley at Chandewadi forest area, has affected the ecosystem.

Yellapur: Yellapur taluk is a home for rich flora and fauna, rugged altitudes and numerous waterfalls, thick forest patches and teakwood forests. Central part of the taluk consist of the semi-evergreen to moist deciduous type of forests, Agabail ghat is most dominated with ever green forest cover. The northern part of Yellapur consists of teak forests. Bamboo is also plenty, which are confined to the catchment area of Bedthi. The land use analysis (Figure 9 (i) & table 8 (i)) show the decline of evergreen forests from 75.28% (1973) to 18.98% (2013). Other land uses include built-up (1.15%), teak plantations (13.49%) followed by Acacia (24.41%), crop lands (7.70%) and coconut/areca nut plantations in valleys of Bedthi river covering 1.40%. Mining at Bisgod and other regions have left indelible footprint of adverse land use changes.

Table 8 (i): Land use analysis of Yellapur

Taluk: YELLAPUR				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	188.78	0.14	1508.92	1.15
Water	87.85	0.07	1574.59	1.20
Crop land	6585.9	5.02	10,104.35	7.70
Open fields	205.78	0.16	2206.68	1.68
Moist deciduous forest	**10,836.81**	**8.26**	**31,907.58**	**24.33**
Evergreen to semi evergreen forest	**98,723.72**	**75.28**	**24,893.29**	**18.98**
Scrub/grass	7265.22	5.54	6964.79	5.31
Acacia/ Eucalyptus/ hardwood plantations	**1238.46**	**0.94**	**32,013.85**	**24.41**
Teak/ Bamboo/ softwood plantations	**2643.48**	**2.02**	**17,689.37**	**13.49**
Coconut/ Areca nut / Cashew nut plantations	170.68	0.13	1841.85	1.40
Dry deciduous forest	3199.01	2.44	437.21	0.33
Total	131145.7			

Haliyal: Haliyal taluk is referred as teak gate way of Uttara Kannda district. Haliyal comprise teak pole area tending to scrub type at the border of Dharwad district. The evergreen forests are found towards the western side in the lower portion of the Kali river valleys.

Table 8 (j): Land use analysis of Haliyal

Taluk: HALIYAL				
Year	1973		2013	
Category	Ha	%	Ha	%
Built-up	**773.79**	**0.90**	**3802.77**	**4.42**
Water	185.08	0.22	2264.48	2.63
Crop land	15857.04	18.42	22326.84	25.95
Open fields	976.57	1.13	3657.53	4.25
Moist deciduous forest	18107.59	21.04	10056.96	11.69
Evergreen to semi evergreen forest	**30507.53**	**35.45**	**2227.70**	**2.59**
Scrub/grass	2191.32	2.55	371.58	0.43
Acacia/ Eucalyptus/ hardwood plantations	1421.00	1.65	22137.25	25.73
Teak/ Bamboo/ softwood plantations	2948.72	3.43	14870.28	17.28
Coconut/ Areca nut plantations	0.00	0.00	711.76	0.83
Dry deciduous forest	**13096.92**	**15.22**	**3621.01**	**4.21**
Total	86065.57			

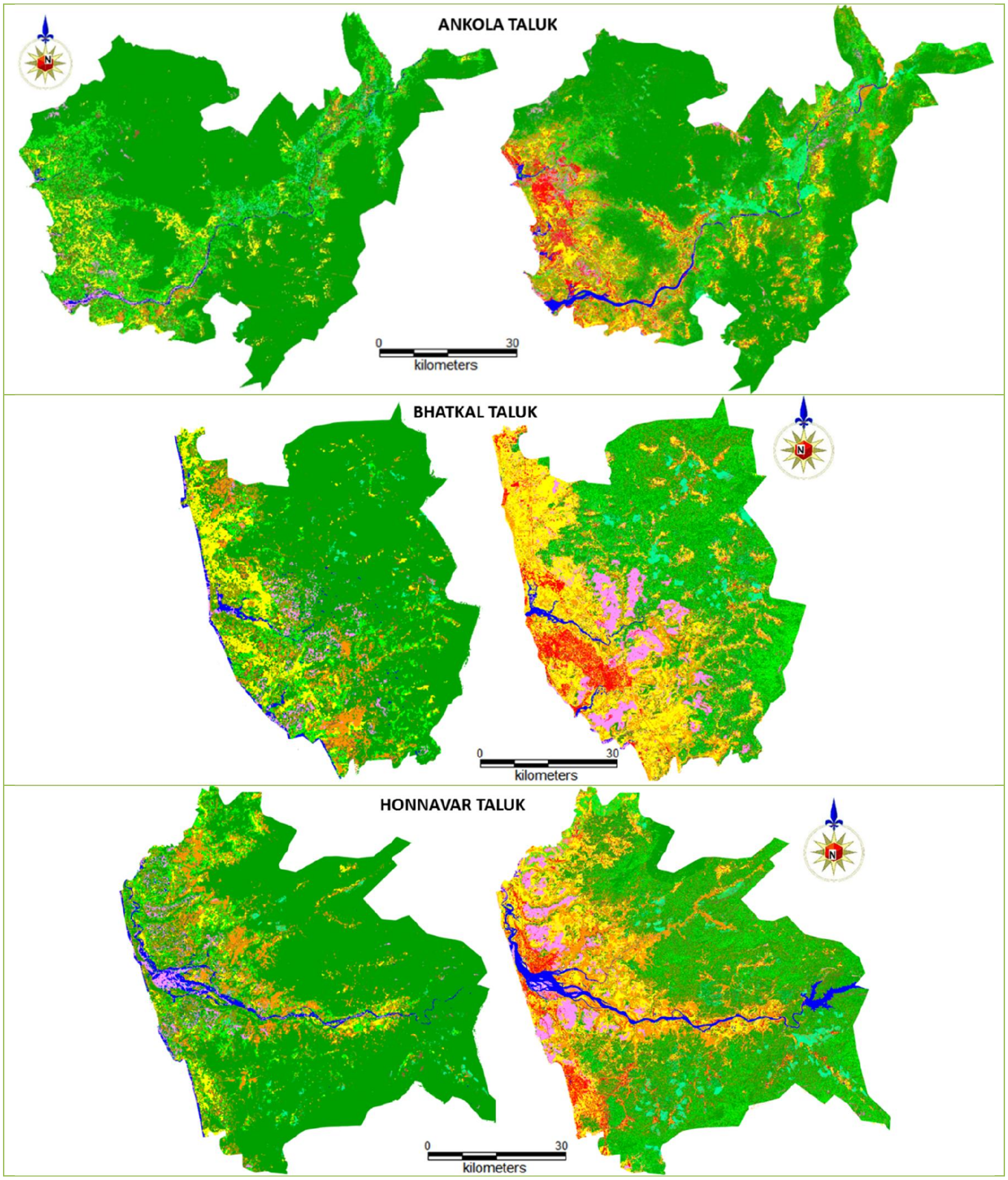
The land use analysis (Figure 9 (j) & table 8 (j)) shows 4.42% area is under built-up, 11.69% area is under moist deciduous forest. The area under different plantation activities constitutes 25.73% and 17.28%. The people of this region are dependent on agriculture which covers 25.95% area. The tourism activities are higher than all taluks because of Anshi-Dandeli tiger reserve, Anshi hornbill's national park, Kali river rafting and many more jungle resorts. The intense plantation activities are observed in this region due to ease of access to roads and climatic factors. Forest fire occurs in the regions where natural vegetation has been altered seriously by intervention or monoculture plantations. The same problem can also observed in Yellapur, Mundgod taluks where fires are affecting ground vegetation and biodiversity.

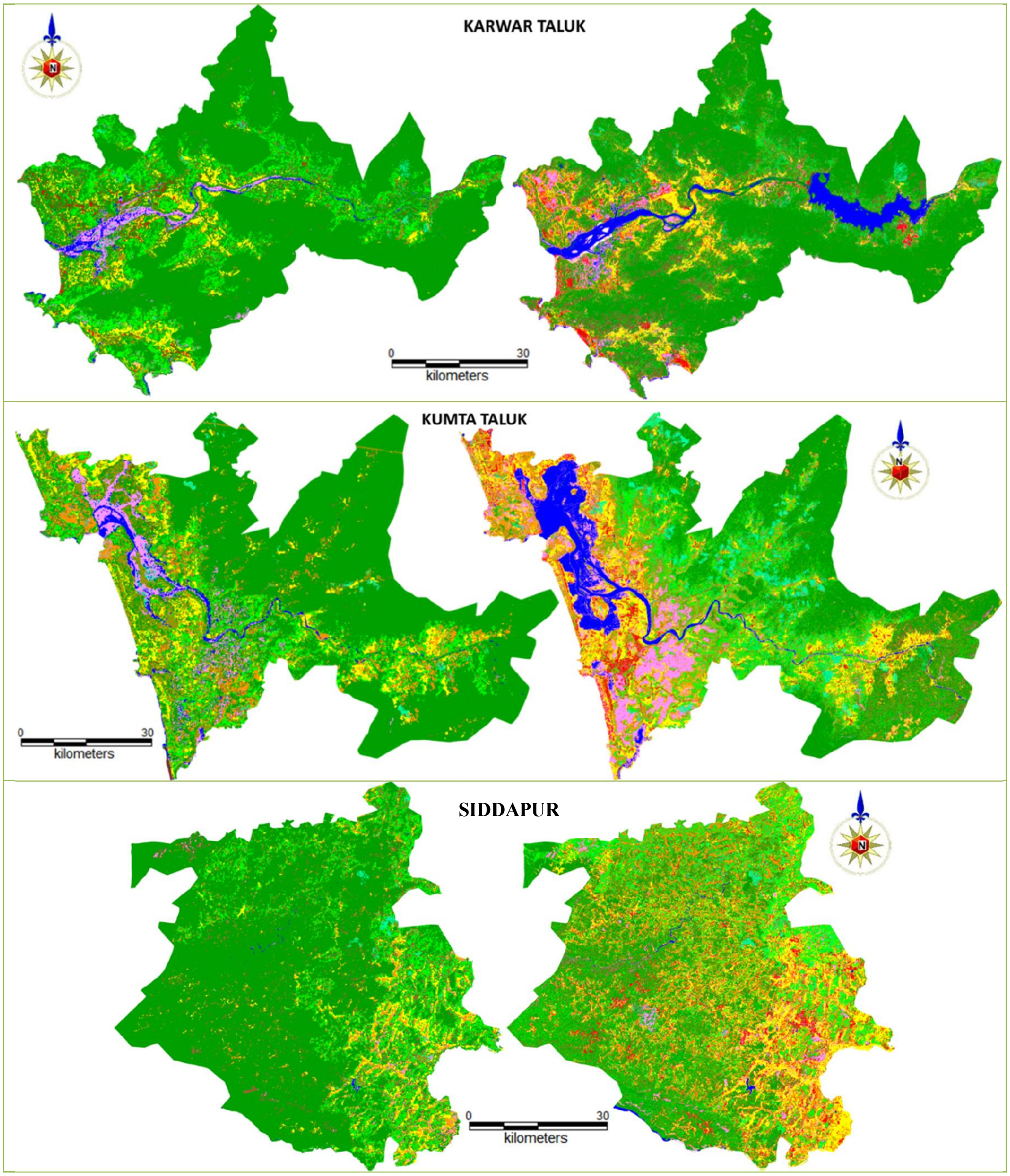
Mundgod: Mundgod taluk comprises of scrub forests, eastern portion comprises of teak plantation (towards Dharwad district) and the western region consists of dense forests. Semi-evergreen patches are seen in the southwest and the perennial river belts. Government of India in the early 1960s, in consultation with the state Government of Karnataka has provided 4,000 acres (16 km^2) of mostly forest land to Tibetan refugees. Attivery Bird sanctuary has become one of major tourism spots of taluk. The land use (Figure 9 (k) & table 8 (k)) of the taluk shows built-up area has increased to 7.06% from 1.36% and agriculture has increased from 18.09% to 30.7% during 1973 to 2013. Dry deciduous forest has declined from 12.75% (1973) to 5.51% (2013). The major portion is under plantations of Forest department, which constitutes 23.74% of Acacia/Eucalyptus and 14.91% of Teak/Bamboo plantations. The agriculture is major source of economy of the people which covers 30.7% area of the taluk. The development pressure from adjacent regions of Dharwad district and small scale industries has been playing in land use changes during the last two decades.

Table 8 (k): Land use analysis of Mundgod

Taluk: MUNDGOD				
Year	**1973**		**2013**	
Category	**Ha**	**%**	**Ha**	**%**
Built-up	**925.02**	**1.36**	**4738.39**	**7.06**
Water	125.82	0.18	388.60	0.58
Crop land	12325.79	18.09	20612.31	30.70
Open fields	4175.39	6.13	5462.65	8.14
Moist deciduous forest	**12217.84**	**17.93**	**4079.23**	**4.59**
Evergreen to semi evergreen forest	**14056.26**	**20.63**	**1017.40**	**1.52**
Scrub/grass	7925.01	11.63	772.26	1.15
Acacia/ Eucalyptus/ hardwood plantations	**1288.19**	**1.89**	**15943.61**	**23.74**
Teak/ Bamboo/ softwood plantations	**6016.14**	**8.83**	**10013.75**	**14.91**
Coconut/ Areca nut plantations	373.64	0.55	1416.47	2.11
Dry deciduous forest	8701.08	12.77	3701.77	5.51
Total	68130.16			

Figure 9 (a to k) shows land use map of each taluk of the district

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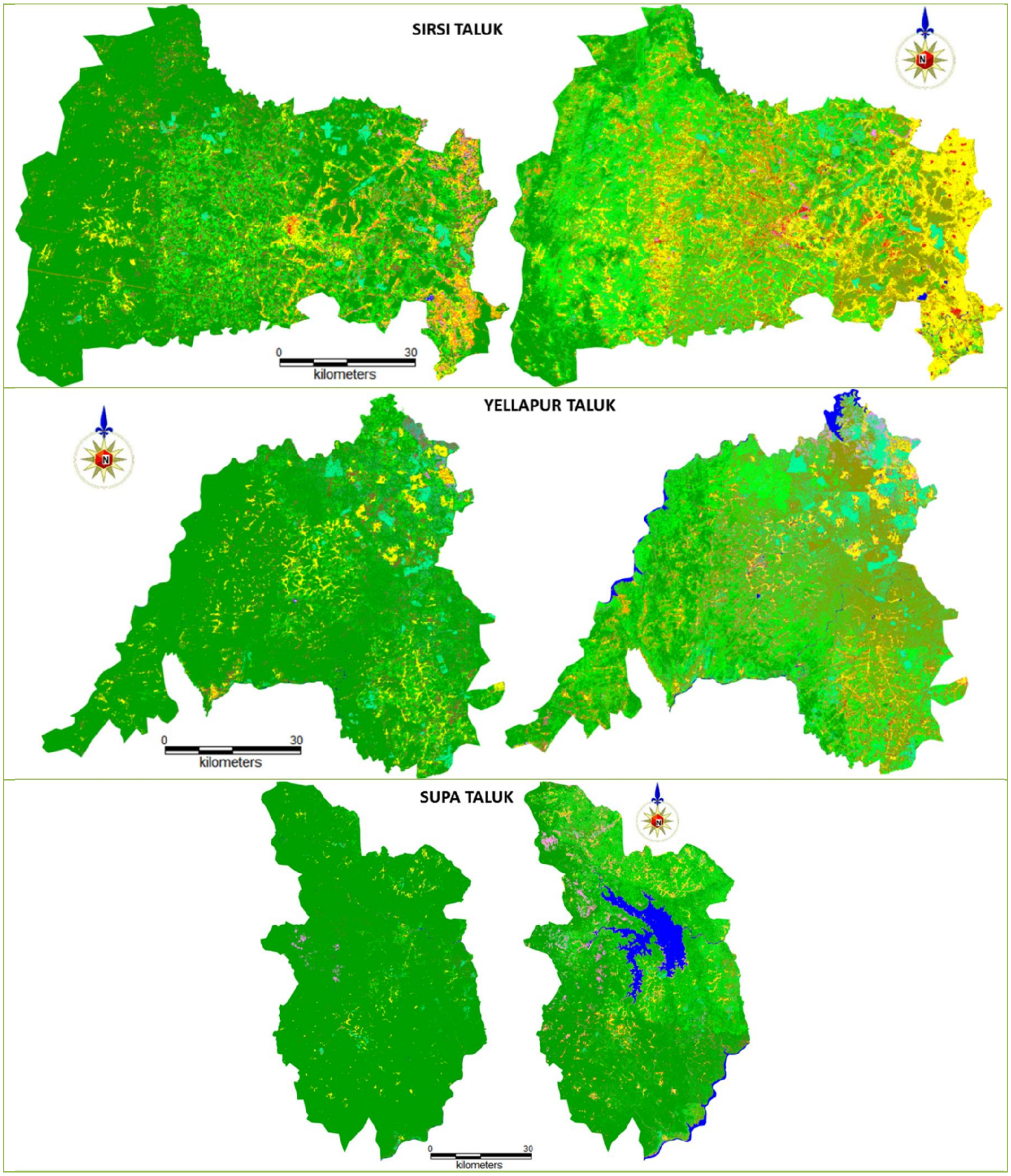
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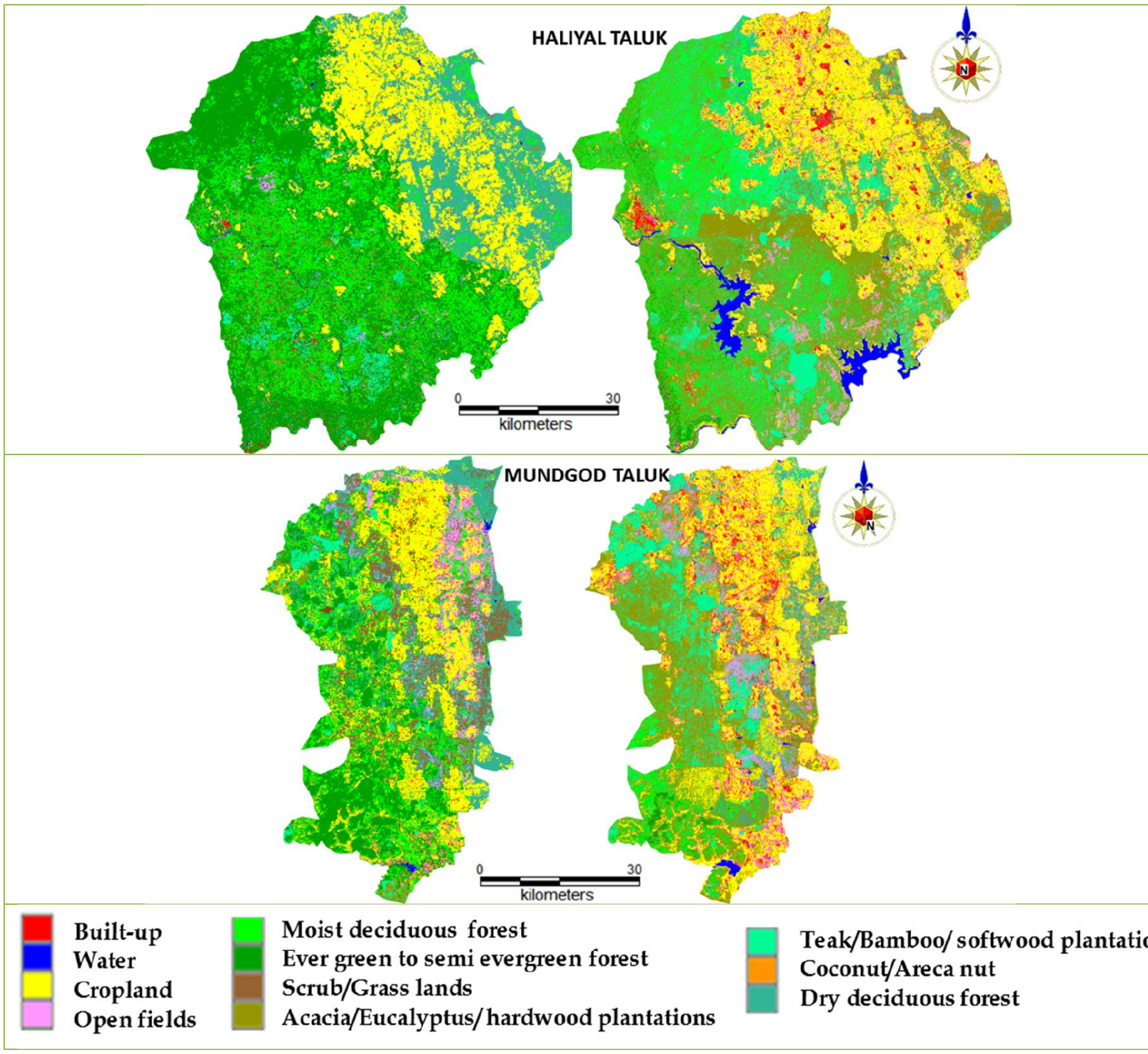


LU across agro-climatic zones: Agro-climatic zone wise land use analysis has been carried out to understand LULC dynamics in the respective zones. Figure 10 gives the overall LU changes across three agro-climatic regions in the district. Forest cover has declined from 81.75 (1973) to 60.98% (2013) in the coastal zone, 91.45 (1973) to 59.14% (2013) in the Sahyadrian interior, and 69.26 (1973) to 16.76% (2013) in plains zone. The coastal region with evergreen to semi evergreen forests in 1973 (Figure 11), show a declining trend. The increase in the population and built-up environs led to conversion of natural vegetation. The intensification of market based agriculture practices like plantation of coconut/ areca nut/cashew nut in Honnavar, Kumta, etc. led to loss of natural forest cover. Karwar taluk has witnessed many developmental projects - construction of series of dams, industries. The identification of pattern of economic development across the district is equally complex, including areas that depend upon forests only as inputs. The unplanned developments have destructed the large tract of forest patches. Remnant rainforest patches were threatened and are at the verge of disappearance. The loss of forest area is not uniform among all the taluks. The plain topography has allowed more land under cultivation. Urbanisation, transportation, industrialisation and other infrastructure developments are expanding day by day. Manganese mining is restricted to Supa taluk; other than transport, urbanized regions, construction of hydro projects, Kaiga nuclear projects engrossed large amount of forest cover in the district.

Sahyadri Interior regions with tropical evergreen forest and semi-evergreen forest to moist deciduous forest cover. The Sahyadri interior forests are mosaics of primary relic forests with network of perennial streams acting as promoters of watershed vegetation. The temporal analysis reveals of the implications of unplanned human interventions leading to the large scale changes in the landscape (Figure 12) affecting the local people with the reduced forest goods and water. Supa taluk had highest forest cover in 1973 (93.56%) changes to 58.51%(2013) due to the hydroelectric projects with series of dams. The intensive horticulture and plantation activities in Siddapur, Sirsi taluks have deteriorated the evergreen forests. Large scale destruction of forests through NTFPs (non-timber forest products) collection driven by market forces through middlemen (contractors) has degraded forests.

Haliyal and **Mundgod** taluks make the transitional zone of the district, which are more prone to economic activities. The market based cropping pattern and forest department based initiatives for plantation of exotic species shown equally adverse effects on forests of this region (Figure 13). The shift is towards intensive commercial oriented horticulture and commercial plantations. Agriculture area has increased with 25.95% in Haliyal and 30.7% in Mundgod. 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 total forest plantations cover extends to 30-35% of both taluks total geographical area.

Figure 10: Land use changes across agro climatic zones of the district

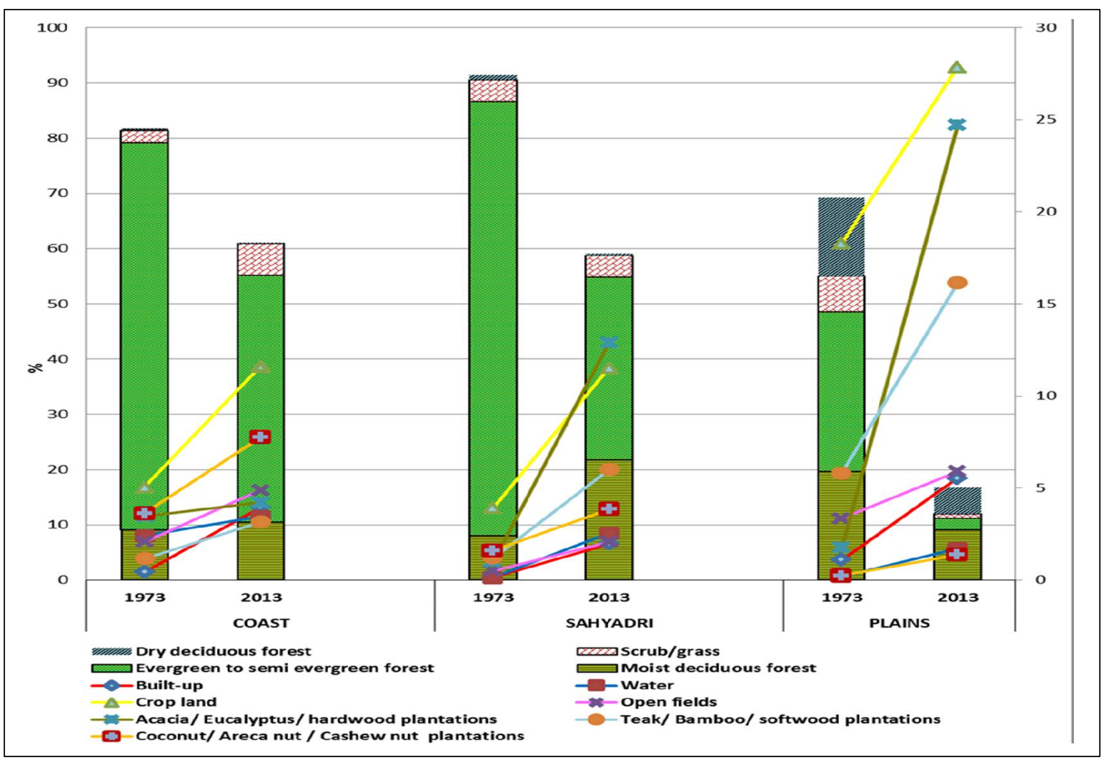


Figure 11: **Land use pattern of Coastal taluks 1973-2013**

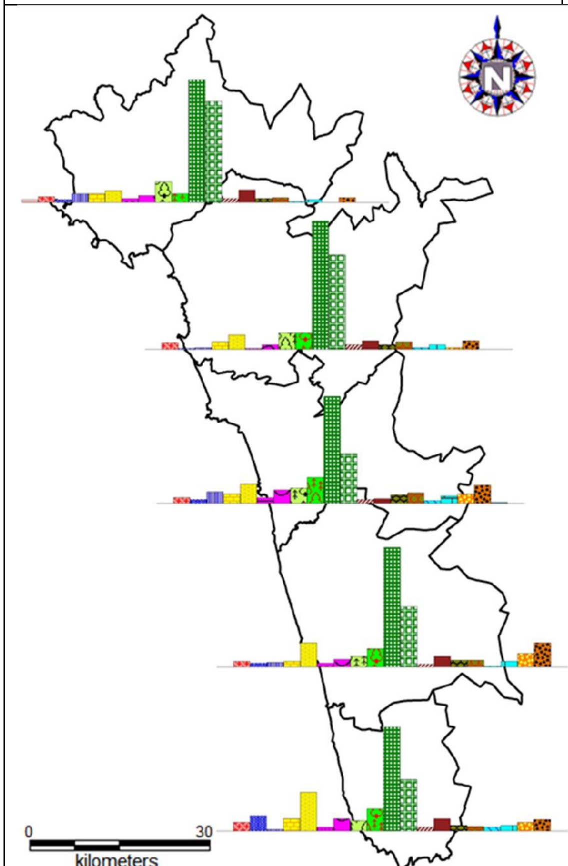


Figure 12: **Land use pattern of Sahyadri Interior taluks 1973-2013**

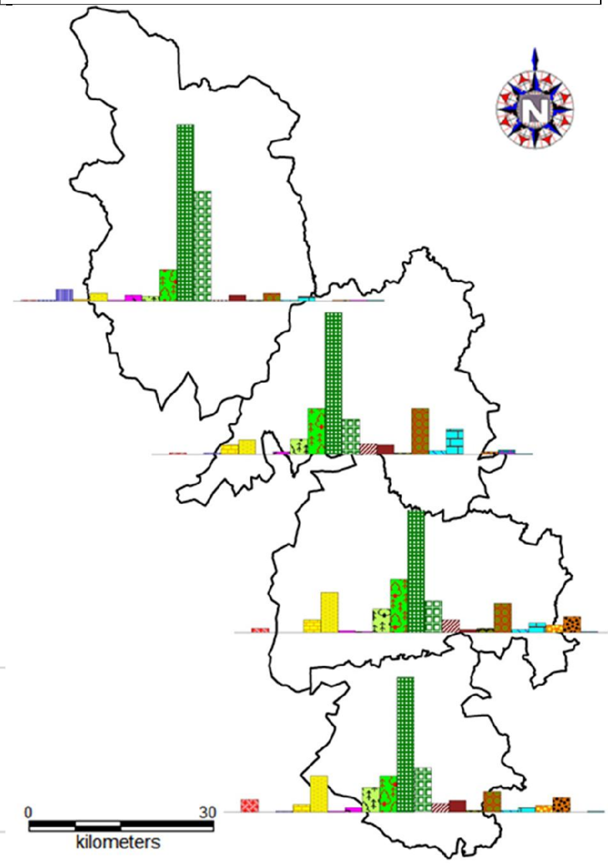
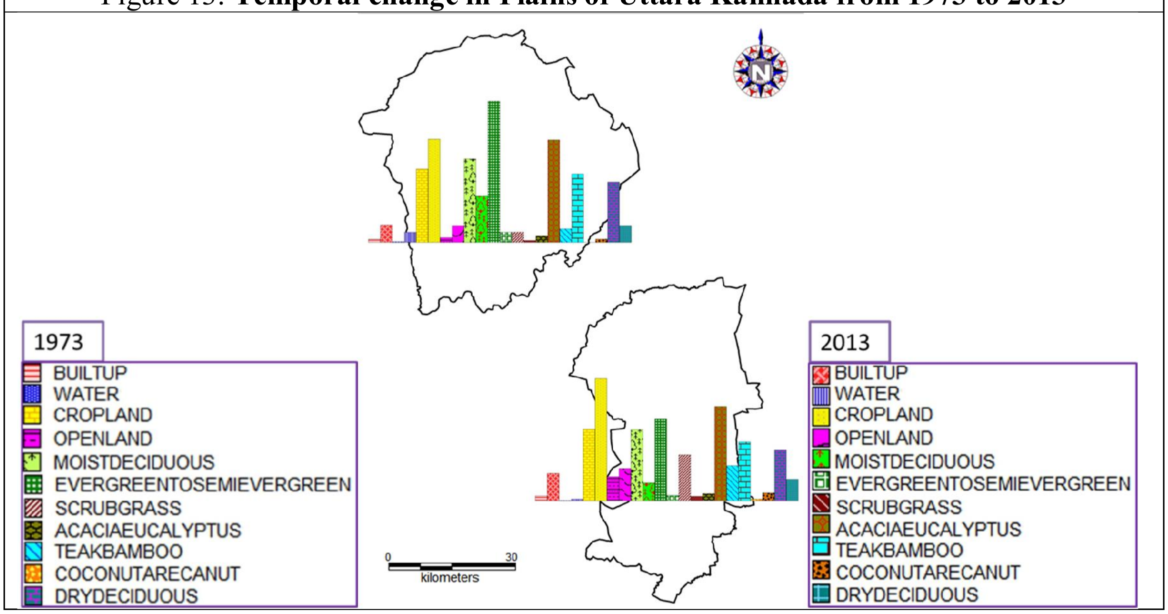


Figure 13: **Temporal change in Plains of Uttara Kannada from 1973 to 2013**



Conclusion:

The land use land cover analysis of Uttara Kannada region at temporal scale is assessed with help of remote sensing data during 1973 to 2013. Landscape has changed significantly over the last four decades due to various change trajectories. Evergreen forests have declined from **67.73**% (1973) to **32.09**% (2013) and area under human habitations and paved surfaces have reached 3.04% (2013). Forest cover has declined from 81.75 (1973) to 60.98% (2013) in the coastal zone, 91.45 (1973) to 59.14% (2013) in the Sahyadrian interior, and 69.26 (1973) to 16.76% (2013) in plains zone.

Costal taluks deforestation tendency is due to housing, agriculture, transportation and communication. Sirsi, Siddapur, Haliyal, Yellapur, Mundgod regions loss of forest area has occurring due to grabbing of vegetated areas to farmland, settlement purposes by disturbing local ecology. Market based economy has motivated Honnavar, Siddapur regions conversion of land for commercial crops. The higher degrees of destruction of forests are leading to change in soil hydraulic properties, leading to overland flows and 'flash flood' of streams. One such case is highly degraded sites near Honnavar in the coastal foothills. Repeated fires make the forests drier, compact the soil and promotes erosion. The conception of forest monocultures has altered the forest structure from multi canopied tropical evergreen, semi-evergreen to moist deciduous with absence of natural ground vegetation. Those forests are used to be primary source of biodiversity and water conservation.

Regeneration and planting new seedlings where regeneration is poor will help in conservation of natural forests and regeneration of the degraded areas of the district. Encroachment of forests and swamps need to be controlled by regulatory authorities, which will help in maintaining the sustenance of natural resources. Watersheds with native vegetation with water availability throughout the year are also repositories of biodiversity. The information of LULC dynamics aided in analysing underlying causes of changes, which help in the design of location specific management strategies, focussing on conservation and restoration of ecosystems.

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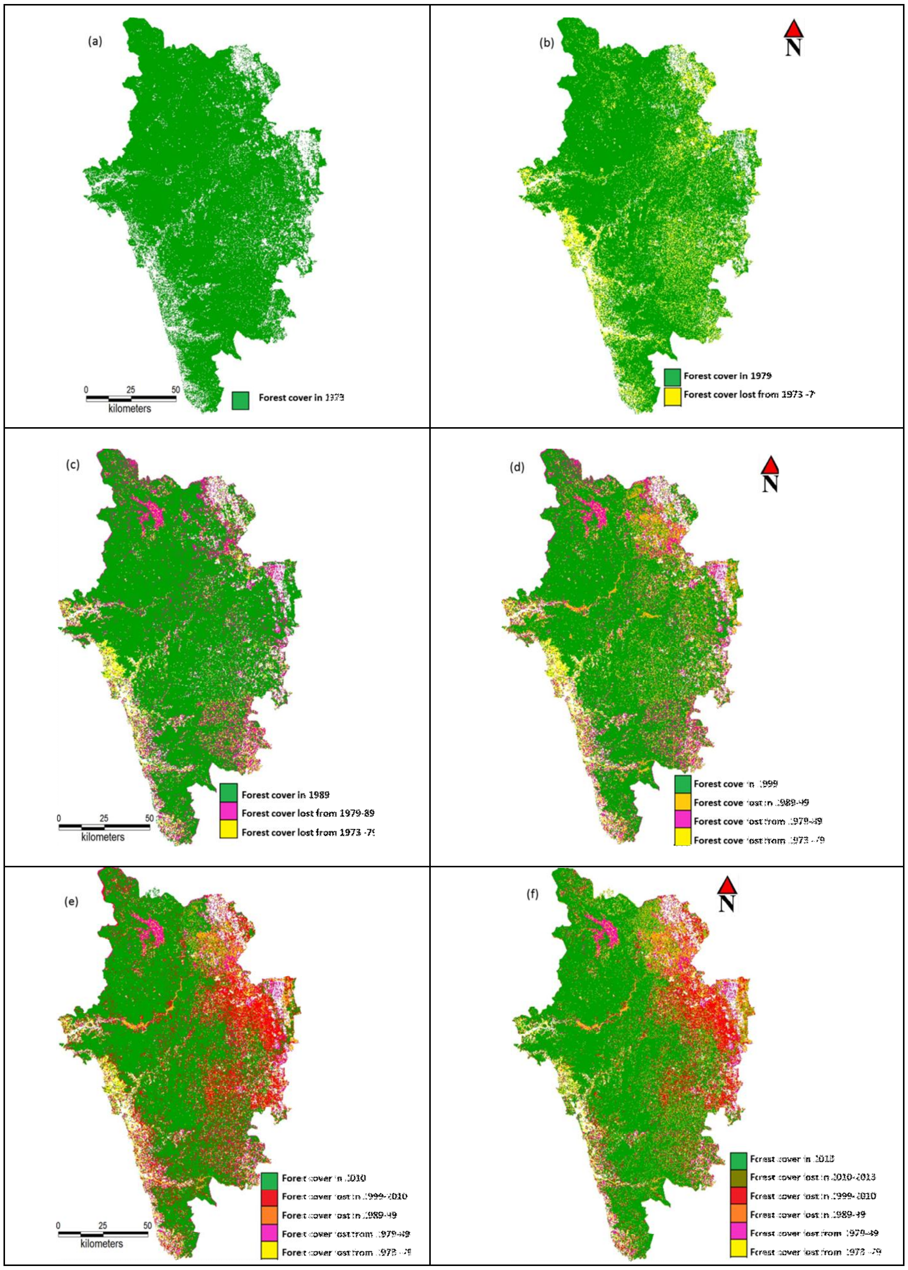

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