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Land Use Dynamics at Padubidri, Udupi District with the Implementation of Large Scale Thermal Power Project

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Abstract: Large scale land use changes leading to deforestation has attracted attention since the mid-19th century as the process is associated with issues related to global warming, consequent climate changes, alteration of biogeochemical cycles, alterations in the regional hydrological cycles, loss of endemic biodiversity apart from impacting the livelihood of the native population. Field research was undertaken in conjunction with the use of multi-resolution remote sensing data to assess the changes in the land use with the implementation of a thermal power project. This paper focuses on a land use land cover changes that have occurred due to the establishment of a 1200 MW power plant at Padubidri in the coastal district of Udupi, Karnataka. The results indicate that the vegetation has decreased from 8.1 (2003) to 4.24% (2011) while the area under built-up has increased from 5.26 to 8.1%.

Keywords: *Land Use Dynamics, Udupi District, Remote Sensing, Thermal Power Plant*.

Introduction:

Human-induced land use changes and consequent enhanced greenhouse gas (GHG) emissions have been considered to be the prime driving force in the global warming and changes in the climate. In this context, understanding the process of land use changes has been vital towards mitigating the impacts of climate changes. Land use/ Land cover (LULC) dynamics and its effects on ecological and hydrological process and on human livelihood has constituted major concerns today, evident from the consideration of LULC change as an important climate forcing driver (NRC, 2005). Land management strategies involving the conversion of natural forests for agricultural and industrial activities (Hammett, 1992) are the causal factor for the changes in the land use. LULC changes are local and place specific, collectively they are features of global environmental change. Land use modification alter the structure of the landscape and hence the functional ability of the landscape. Continual, historical, and precise information about the LULC changes of the Earth's surface is essential for evolving appropriate management strategies towards the sustainable development of the landscape (Abd El-Kawy et., al 2011). Environmental and ecological consequences of landscape transformation are more evident in natural ecosystems where their sustainability, multi-functional role and values are threatened (Narumalani et al., 2004; Schulz et al., 2010). Remote Sensing and Geographic Information System are main platforms of data acquisition and analysis of LULC changes (Eastman and Fulk, 1993; Ehlers et al., 1990; Harris and Ventura, 1995; Dewan and Yamaguchi, 2009). Multi-resolution (temporal, spatial and spectral) remote sensing data available since 1970's aid in the analysis of long term environmental changes and impacts of human induced changes in the landscape (Xu et al., 2005; Berberoglu and Akin, 2009; Yu et al., 2011). Spatially explicit temporal data helps in the inventorying, mapping and monitoring spatio-temporal processes and changes. Understanding the causal factors with these changes is essential to develop mitigation and adaptation policies to minimize future disturbances while arresting further degradation (Marcucci, 2000).

Land Use, Land Cover and Its Change:

Land cover (LC) refers to the features present on the earth surface. Land cover configuration is stated as a unified reflection of the existing natural resources and natural processes that are dynamic in nature. Mapping, quantifying, and monitoring the physical characteristics of land cover has been widely recognized as a key element for natural resource management and sustainable planning activities (Nemani & Running, 1996; Barlage et al., 2004). Land use refers to the human induced changes for agricultural, industrial, residential, recreational purposes. The main drivers of land use can be stated as land management policies, population, agricultural production and urban expansion. Land use change alters the homogeneous landscape into heterogeneous mosaic of patches. Almost 40 percent of Earth's land surface had been converted to cropland and permanent pasture by early 1990s,. This conversion has occurred largely at the expense of forests and grassland (Ramachandra and Shruthi, 2007).

LULC change influences the interaction of ecological, geographical, economic, and social factors (Zang and Huang, 2006; Geist and Lambin, 2006). The impacts of LULC changes on a landscape with respect to wind regime, temperature, soil moisture, water vapor, and cloud development has been accounted through numerous models (Adegoke et al., 2007; Narisma and Pitman, 2003; Gero and Pitman, 2006; Sen Roy et al., 2007; Sen Roy et al., 2011). The structure and composition of landscapes undergoes a rapid change as a result of human related activities. The changes in the mosaic of landscape elements are considered to influence significantly the processes and functions of ecological systems. Quantifying landscape spatial patterns and their changes provide important information for monitoring and assessing the effects of human induced changes on landscape.

LULC Change Detection:

Multi resolution data acquired at regular intervals have been useful in mapping and monitoring the changes in LULC. The collection of remotely sensed data covering larger spatial extent enables the analyses of changes at local, regional and global scales over time. This also provides an important link between intensive, localized ecosystem management and sustainable planning (Wilkie and Finn, 1996) and it presents a synoptic view of the landscape at low cost (Lillesand and Kiefer, 1987). Remote sensing data along with GPS (Global positioning system) help in effective land cover analysis (Ramachandra and Kumar, 2004). Successful utilization of remotely sensed data for land cover and land use change detection requires careful selection of appropriate data set. Good quality of RS data, strict geometric registration and radiometric normalization, and suitable training data selection are important for successful implementation of the LULC change detection.

Objective:

The objective of this study is to assess the LULC changes due to the implementation of large scale thermal power project. This involves the quantification of the spatio-temporal LULC change in the landscape from 2003 to 2011 using remote sensing data.

Study Area:

The Study area extends from 13.206086° N latitude 74.793109° E longitude to 13.112899° N latitude to 74.799948° E longitude in Padubidri in the coastal district of Udupi, Karnataka. The focus area of the current study is a core zone of 2 km around Yellur village. The region is sandwiched by Western Ghats in the east and Arabian Sea in the west. The river Shambhavi, a tributary to river Mulki flows nearly 4 km south of the Yellur village. The region covers buffer of 5 km surrounding coal based thermal power plant. The study area consisted of vegetation of semi evergreen type with diverse species. The area has a high conservation value as it is a habitat for many rare and endangered species, with numerous indirect and direct ecosystem services elevation varies from mean sea level (0 m) to 65 m and high lands are concentrated in the north to east sector. The soil in the interiors of the region is majorly lateritic red type with high porosity and permeability while the coast is rich in alluvium. Soil texture varies from fine to clayey skeletal to loamy skeletal. It is acidic in nature due to heavy runoff, abundant in nitrogen but deficient in potassium and phosphorous. Due to its high infiltration rate, inter-connected aquifers of the region are recharged during rains. The vegetation in the region is largely evergreen and deciduous type.

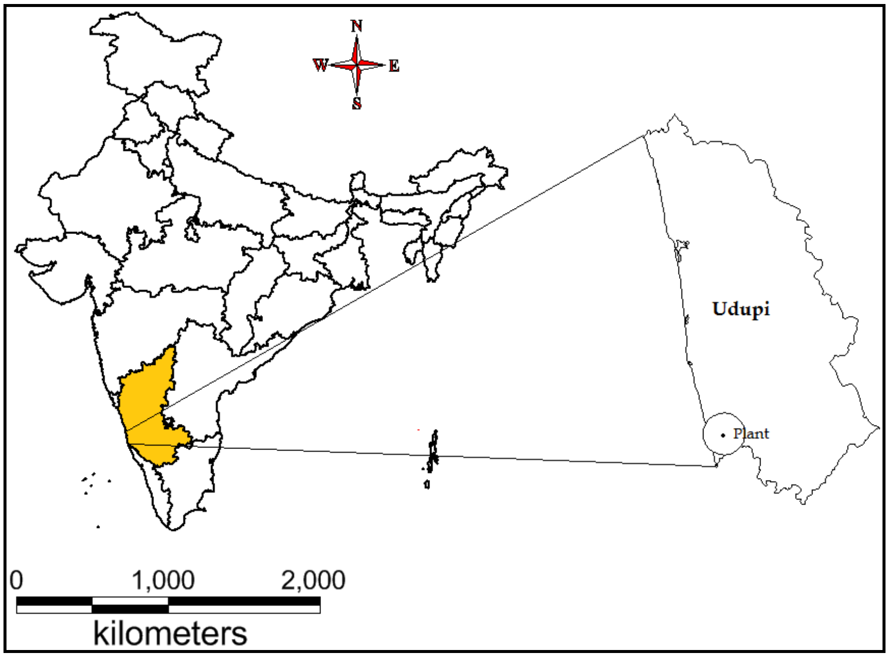

Figure 1: *Study Area*

Figure 2 Illustrates the study area as seen in Google Earth, showing 5KM buffer area considered.

Figure 2: Study Area with 5 Km Buffer Overlaid on Spatial Data (Google Earth)

Data:

Remote Sensing (RS) Data:

The RS data used in the study are IRS 1C LISS III pan merged data (2003), IRS – P6 LISS-III (2011), and Google Earth (http://earth.google.com, 29th November 2010 and 28th December 2003). The summary characteristics of datasets used in the current study are summarized in Table 1.

Table 1: *Details of Remote Sensing Data*

Year	Satellite	Date of Acquisition	Resolution (m)
2003	IRS 1C LISS III – Pan Merged	23/01/2003	5m
2011	IRS P6 LISS III	08/01/2011	23.5

Ancillary Data:

The ancillary data provides the supplemental information to assist the interpretation of different land use types. Besides remote sensing data, many other data sources have been used in the study. Ancillary data includes topographic map (The Survey of India).at varying scales 1:250 000 (48K) and 1:50000 (48K-11,12, 15 and 16)

Method:

Figure 3 depicts the procedure followed in the study. The preprocessing of remote sensing data includes atmospheric correction and geometric correction in order to enable correct area measurements, precise localization and multi-source data integration (Buiten, 1988, Jixian et.al, 2007). The remote sensing data (Indian Remote Sensing Satellites) obtained were geo-referenced, rectified and cropped pertaining to the study area. The temporal data used in the analysis were resampled to 10 m for temporal comparisons with uniform spatial resolutions. Geo-registration of remote sensing data has been done using ground control points (GCPs) 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.

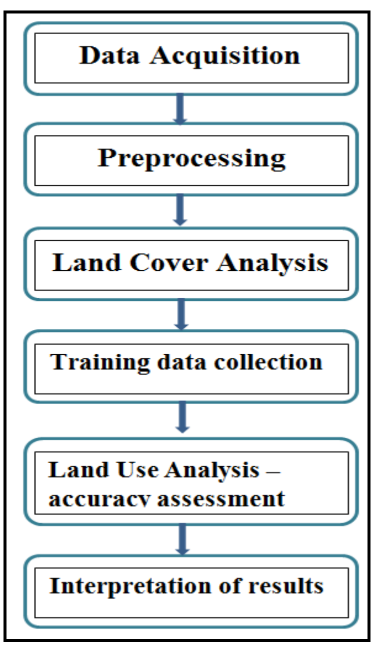

Figure 3: *Protocol for Remote Sensing Data Analysis*

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 measured from a map or located in the field (using GPS). All datasets acquired are geometrically corrected.

Land Cover and Land Use Analysis:

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. The capability of capturing changes in land cover and extracting the change information from satellite data requires effective change detection techniques (Roy et al., 2002 and Shalaby et al., 2007).The monitoring of land cover involves the computation of vegetation indices. Vegetation indices help in mapping the regions under vegetation and non-vegetation (soil and water). Among all techniques of land cover mapping Normalised difference Vegetation Index (NDVI) is most widely accepted and applied (Weismiller et al., 1977, Jensen and Toll, 1982, Nelson, 1983, Ramachandra et al., 2009). The land cover analysis was done using NDVI (Normalized Difference Vegetation Index). Calculation of NDVI for Multi-temporal data is advantageous in areas where vegetation changes rapidly. NDVI is based on the principle of spectral difference based on strong vegetation absorbance in the red and strong reflectance in the near-infrared part of the spectrum. NDVI is computed using visible Red and Near Infra-Red (NIR) bands of the data. Healthy vegetation absorbs most of the visible light 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), using Eq. (1)

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

Very low values of NDVI (-0.1 and below) correspond to soil or barren areas of rock, sand, or urban built-up. Zero indicates the water cover. Moderate values represent low density vegetation (0.1 to 0.3), while high values indicate thick canopy vegetation (0.6 to 0.8).

Land Use Analysis:

The method involves i) generation of false colour composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in

FCC) covering 15% of the study area and 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 v) 60% of the training data has been used for classification of the data, while the balance is used for validation or accuracy assessment.

Training data was collected in order to classify and also to validate the results of the classification. The land use analysis was carried out with supervised classification scheme with selected training data. The supervised classification approach is adopted as it preserves the basic land cover characteristics through statistical classification techniques using a number of well-distributed training pixels. Maximum Likelihood algorithm is a common, appropriate and efficient method in supervised classification techniques by using availability of multi-temporal "ground truth" information to obtain a suitable training set for classifier learning. Supervised training areas are located in regions of homogeneous cover type. All spectral classes in the scene are represented in the various subareas and then clustered independently to determine their identity. The following classes of land use were examined: built-up, water, cropland, open space or barren land, and forest. Such quantitative assessments, will lead to a deeper and more robust understanding of land-use and land-cover change and to more appropriate policy intervention. GRASS GIS (Geographical Analysis Support System) a open source software has been used for the analysis, which has the robust support for processing both vector and raster files accessible at http://wgbis.ces.iisc.ernet.in/grass/index.php.

Accuracy assessments decide the quality of the information derived from remotely sensed data. The accuracy assessment is the process of measuring the spectral classification inaccuracies by a set of reference pixels. These test samples are then used to create error matrix (also referred as confusion matrix), kappa (κ) statistics and producer's and user's accuracies to assess the classification accuracies. Kappa is an accuracy statistic that permits us to compare two or more matrices and weighs cells in error matrix according to the magnitude of misclassification. Accuracy assessment and kappa statistics are included in table 5. This table is used to evaluate the strength of each class as well as the classification as a whole.

Results & Discussion:

Land Cover Analysis:

NDVI computed for 2003 and 2011 is given in Figure 4 and listed in Table 3. This illustrates the spatio temporal changes in the vegetation cover. The vegetation cover 87.32 % (2003) has decreased to 59.76% (2011).

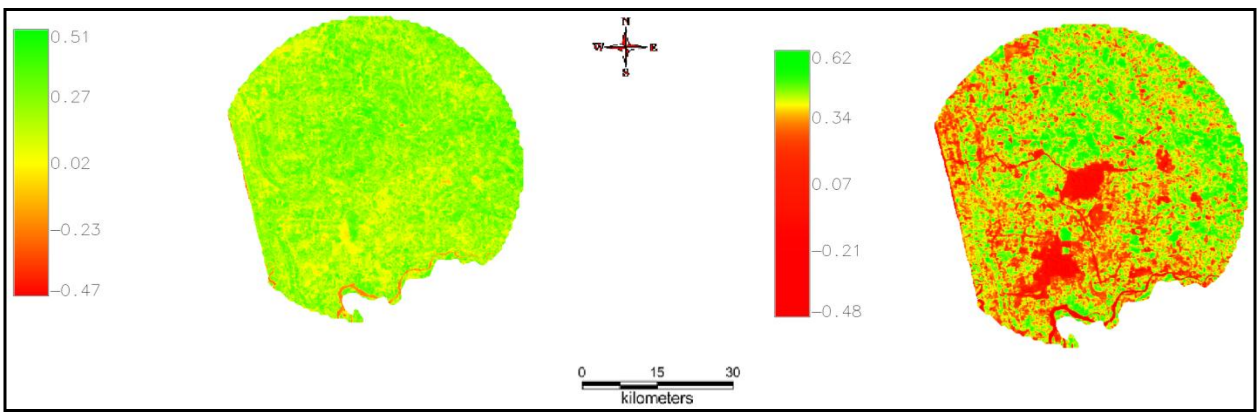

Figure 4: *Land Cover Classification*

Table 3: *Land Cover Analysis*

Year	% Vegetation	% Non-vegetation
2003 (before setting up thermal power plant)	87.32	12.68
2011	59.76	40.24

Land Use Analysis:

The Spatio temporal land use changes during 2003 to 2011 are given in figure 5 and table 4. The built-up land increased from 5.26% (2003) to 8.1% (2011), Vegetation decreased from 8.1% (2003) to 4.24% (2011) emphasising the changes in land use after setting up large scale thermal power plant.

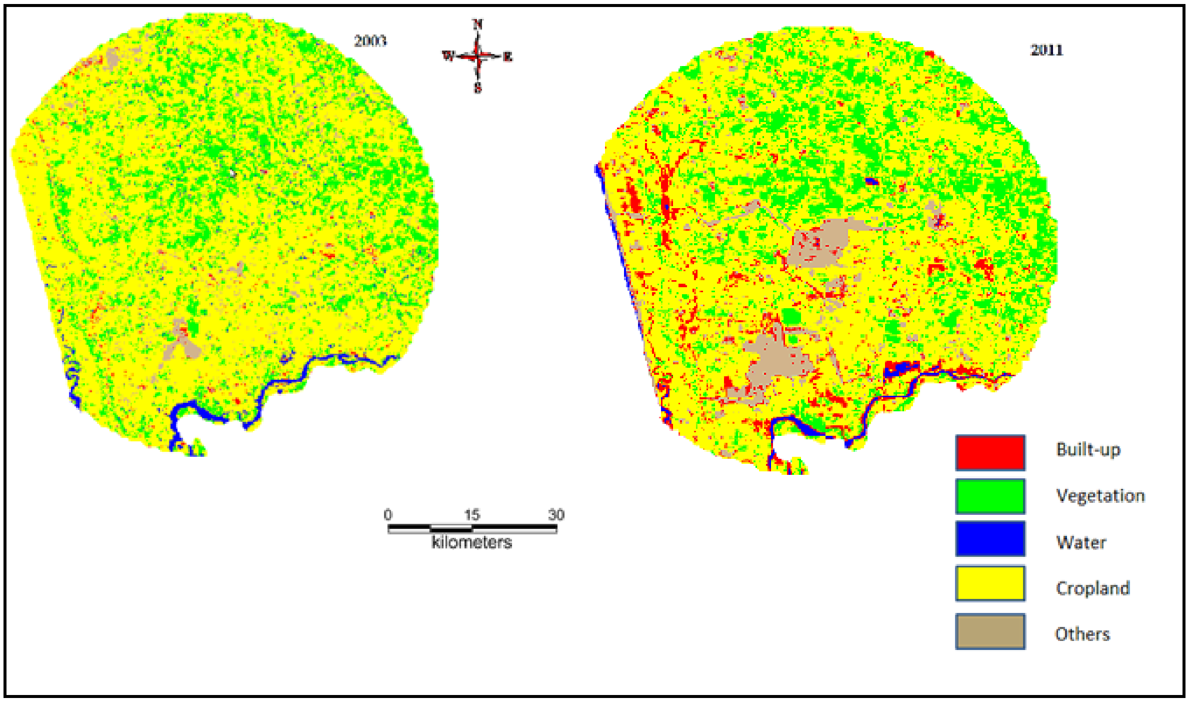

Figure 5: *Land Use Classified Image*

Year →	2003		2011	
Category	Ha	%	Ha	%
Built-up	691.466	6.26	1402.81	12.7
Water	117.085	1.06	104.934	0.95
Cropland	7546.47	68.32	5901.762	53.43
Vegetation	894.70	8.1	468.34	4.24
Others	1796.044	16.26	3167.93	28.68
Total area(Ha)			11045.784	

Table 4: *Spatio-Temporal Land Use Dynamics*

Table 5: *Kappa Statistic and Accuracy Assessment*

Year	**Overall Accuracy**	**Kappa value**
2003	93.515	0.898
2011	95.010	0.906

Table 6: *Producer and User Accuracy Calculated For Each Class*

Year	Land use	Producer's Accuracy	User's Accuracy
2003	Built-up	86.5%	88.1%
	Cropland	94.0%	91.7%
	Vegetation	79.3%	83.3%
	Water	89.8%	94.8%
	Others	94.0%	86.0%
2011	Built-up	96.2%	95.3%
	Cropland	98%	94.8%
	Vegetation	89.6%	84.4%
	Water	98.4%	97.1%
	Others	93.3%	89.6%

Accuracy Assessment:

Kappa statistic summarizes the overall results and measures the difference between the actual agreements in the error matrix which is ranging from 93% to 95% . Accuracy assessment done for the classified data is given in table 5 and table 6 respectively.

Apart from physical land use changes, also observed drying of leaves (leaf burn associated with necrosis, chlorosis, etc.) and reduced crop (agriculture, horticulture) productivities due to the emissions (Particulate matters, Sox, Super saturated saline mist from cooling towers). Phyto-toxicity due to the deposition of dust with contaminants (heavy metals) in the pollen parts has affected the pollination. This is evident form the reduced population of pollinators (bees, etc.) in the region. The reduced crop productivity and contamination of water (due to discharge of effluents and also leakage from fly ash pond) has affected the livelihood of the local people. Spatial analysis also reveals the lack of green barriers / green belt in the region contrary to the guidelines as per the environment norms. As per the environmental policy 2006 and also EIA notification 2006, TPP is supposed to maintain at least 33% green cover. However, poor green cover in the TPP site as well as ash pond site and lack of appropriate buffer, highlight non-compliance of the environmental norms.

Conclusion:

Large scale land cover changes involving the conversion of forests are one of the primary drivers of climate changes. Setting up of thermal power project in the vicinity of the Western Ghats, a global biodiversity hotspot necessitated the study to understand land cover dynamics and associated environmental impacts. This study mapped the (from 2003 to 2011) land use and land cover changes and provide quantitative analysis of LUCC information. Land use analysis was done through the supervised classification approach using Gaussian maximum likelihood classifier. Overall accuracy of the classification ranges from 93.5 to 95% and kappa value ranges from 0.898 to 0.906. Land use changes have been observed subsequent to setting up large scale thermal power plant. The results show that land cover has gradually changed from vegetation and crop land to thermal power plant and associated amenities during this period. This is evdienmt from the reduction of area under vegetation from 87.32% (2003) to 59.76% (2011). Temporal land use analysis reveal that the built-up land increased from 6.26% (2003) to 12.7% (2011) and decline of tree cover from 8.1% (2003) to 4.24% (2011).

The release of supersaturated saline mist due to insufficient desalination has led to the deposition of the salt in the immediate vicinity on plant parts, etc. This affects the morphology and the strength of the plants. Deposition of the saline particles on the foliar parts has resulted in the plasmolysis of the cells thence killing the soft tissues, which are directly exposed. The reduction in the foliar cell densities would in turn result in the decrease in the densities of the chloroplasts leading to reduced photosynthetic activities and lower crop yield. This is evident from the observation of chlorosis and necrotic spots on the vegetative parts of the flora in close proximities. The salt deposition also affects to large extent the reproductive parts as the male and the female reproductory organs of the flora, obstructing fertilisation. Also due to deposition of particulate matters with contaminants on the pollen of the flower has resulted in impairing pollination services affecting fertilization and embryo formation. This is evident from reduced pollinators even in peak phonological season. The phyto-toxicity due to this has affected the crop yield resulting in abandoning 14.77% of crop land without cultivation in recent years. Area under crops has reduced from 68.32% (2003) to 53.43% (2011). Information on spatiotemporal changes in the landscape is essential to understand the consequences of development which would help in implementing location specific appropriate mitigation measures.

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