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Geographic Resources Decision Support System for land use, land cover dynamics analysis

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Abstract

Change detection is the measure of the distinct data framework and thematic change information that can guide to more tangible insights into underlying process involving land cover and land use changes than the information obtained from continuous change. Digital change detection is the process that helps in determining the changes associated with landuse and land cover properties with reference to geo-registered multitemporal remote sensing data. It helps in identifying change between two (or more) dates that is uncharacterised of normal variation. Change detection is useful in many applications such as landuse changes, habitat fragmentation, rate of deforestation, coastal change, urban sprawl, and other cumulative changes through spatial and temporal analysis techniques such as GIS (Geographic Information System) and Remote Sensing along with digital image processing techniques.

GIS is the systematic introduction of numerous different disciplinary spatial and statistical data, that can be used in inventorying the environment, observation of change and constituent processes and prediction based on current practices and management plans. Remote Sensing helps in acquiring multi spectral spatial and temporal data through space borne remote sensors. Image processing technique helps in analyzing the dynamic changes associated with the earth resources such as land and water using remote sensing data. Thus, spatial and temporal analysis technologies are very useful in generating scientifically based statistical spatial data for understanding the land ecosystem dynamics. Successful utilization of remotely sensed data for land cover and landuse change detection requires careful selection of appropriate data set. This paper discusses the land use/land cover analysis and change detection techniques using GRDSS (Geographic Resources Decision Support System) for Kolar district considering temporal multispectral data (1998 and 2002) of the IRS 1C / 1D (Indian Remote Sensing Satellites).

GRDSS is a freeware GIS Graphic user interface (GUI) developed in Tcl/Tk is based on command line arguments of GRASS (Geographic Resources Analysis Support System). It has the capabilities to capture, store, process, display, organize, and prioritize spatial and temporal data. GRDSS serves as a decision support system for decision making and resource planning. It has functionality for raster analysis, vector analysis, site analysis, image

processing, modeling and graphics visualisation. This help in adopting holistic approaches to regional planning which ensures sustainable development of the region.

Keywords: Land use/Land cover Dynamics, Change detection, GIS, Remote Sensing, GRASS, GRDSS

1 Introduction

Land-cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements. Land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. It is the intended employment of management strategy placed on the land-cover type by human agents, and/or managers (LUCC Report series No. 3). Land-use/Land-cover change information has an important role to play at local and regional as well as at macro level planning. The planning and management task is hampered due to insufficient information on rates of land-cover/land-use change. The land-cover changes occur naturally in a progressive and gradual way, however some times it may be rapid and abrupt due to anthropogenic activities. Remote sensing data of better resolution at different time interval help in analysing the rate of changes as well as the causal factors or drivers of changes. Hence it has a significant role in regional planning at different spatial and temporal scales. This along with the spatial and temporal analysis technologies namely Geographic Information System (GIS) and Global Positioning System (GPS) help in maintaining up-to-date land-use dynamics information for a sound planning and a cost-effective decision.

Change detection in watersheds helped in enhancing the capacity of local governments to implement sound environmental management (Prenzel *et al.,* 2004). This involved development of spatial and temporal database and analysis techniques. Efficiency of the techniques depends on several factors such as classification schemes, spatial and spectral resolution of remote sensing data, ground reference data and also an effective implementation of the result.

Coastal environment changes were analysed through qualitative evaluation techniques (Debashis Mitra, 1999). The techniques included change map derived from vegetation index differencing, Image ratioing, image differencing and image regression. The basic principle of all change detection techniques was that the digital number of one date is different from the digital number of another date.

Remotely sensed change detection based on artificial neural networks (Dai *et al.*, 1999) presents a new technique for multispectral image classification using training algorithm. The trained neural network detected changes on a pixel-by-pixel basis in real time applications. The trained four-layered neural network provided complete categorical information about the nature of changes and detected complete land-cover change "from-to" information, which is desirable in most change detection applications.

Post classification change detection techniques with the comparison of land-cover classifications of different dates have limitations, as it does not allow the detection of subtle changes within land-cover categories (Macleod and Congalton, 1998).

In this regard Open Source GIS such as GRASS (Geographic Resources Analysis Support System) helps in land cover and land use analysis in a cost-effective way. Most of the commands in GRASS are command line arguments and requires a user friendly and cost-effective graphical user interface (GUI). GRDSS (Geographic Resources Decision Support System) has been developed in this regard to help the users. It has functionality such as raster, topological vector, image processing, graphics production, etc. Figure 1 depicts the Main menu of GRDSS. It operates through a GUI developed in Tcl/Tk under LINUX. GRDSS include options such as Import / Export (of different data formats), extraction of individual bands from the IRS (Indian Remote Sensing Satellites) data (in Band Interleaved by Lines format), display, digital image processing, map editing, raster analysis, vector analysis, point analysis, spatial query, etc. These are required for regional resource mapping, inventorying and analysis such as Watershed Analysis, Landscape Analysis, etc.

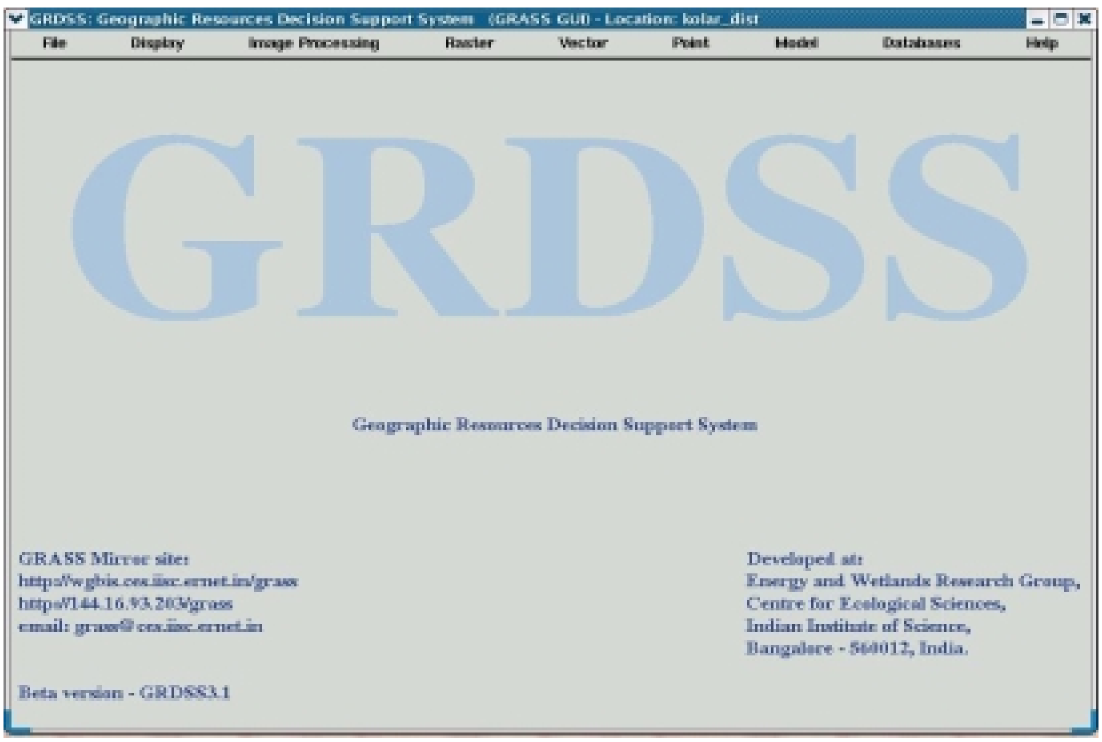

Figure 1: Geographic Resources Decision Support System – Main menu

Objective of this endeavor is to carry out the land use/land cover and temporal change analysis for Kolar district, Karnataka State, India using GRDSS (Geographic Resources Decision Support System).

2 Study area

Burgeoning population coupled with lack of holistic approaches in planning process has contributed to a major environmental impact in dry arid regions of Karnataka. The Kolar district in Karnataka State, India was chosen for this study is located in the southern plain regions (semi arid agro-climatic zone) extending over an area of 8238.47 sq. km. between 77°21’ to 78°35’ E and 12°46’ to 13°58’ N. (shown in Figure 2.)

Kolar is divided into 11 taluks for administrative purposes (Bagepalli, Bangarpet, Chikballapur, Chintamani, Gudibanda, Gauribidanur, Kolar, Malur, Mulbagal, Sidlaghatta, and Srinivaspur). The distribution of rainfall is during southwest and northeast monsoon seasons. The average population density of the district is about 2.09 persons/hectare.

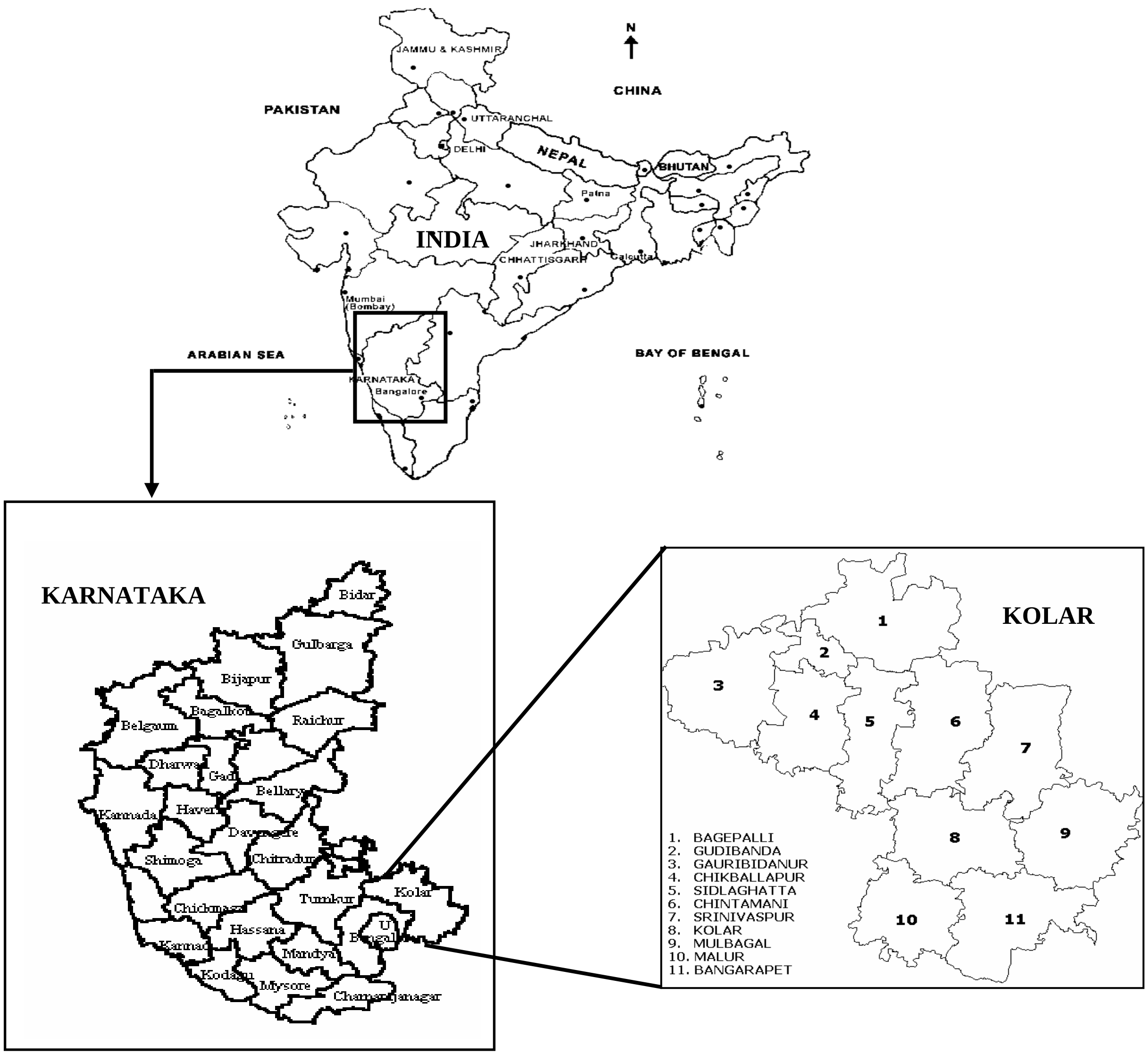

Figure 2: Study area – Kolar district, Karnataka State, India

The Kolar district forms part of northern extremity of the Bangalore plateau and since it lies off the coast, it does not enjoy the full benefit of northeast monsoon and being cut off by the high Western Ghats. The rainfall from the southwest monsoon is also prevented, depriving of both the monsoons and subjected to recurring drought. The rainfall is not only scanty but also erratic in nature. The district is devoid of significant perennial surface water resources. The ground water potential is also assessed to be limited. The terrain has a high runoff due to less vegetation cover contributing to erosion of top productive soil layer leading to poor crop yield. Out of about 280 thousand hectares of land under cultivation, 35% is under well and tank irrigation (http://wgbis.ces.iisc.ernet.in/energy/ paper/).

The main sources of primary data were from field (using GPS), the Survey of India (SOI) toposheets of 1:50,000, 1:250,000 scale and multispectral sensors (MSS) data of the IRS (Indian Remote Sensing satellites) -1C and IRS -1D (1998 and 2002). LISS-III MSS data scenes corresponding to the district for path-rows (100,63) (100,64) and (101, 64) was procured from the National Remote Sensing Agency, Hyderabad, India (http://www.nrsa.gov.in). The secondary data was collected from the government agencies (Directorate of census operations, Agriculture department, Forest department and Horticulture department).

3 Methodology

The methodology of the study involved -

1. Creation of base layers like district boundary, district with taluk and village boundaries, road network, drainage network, contours, mapping of waterbodies, etc. from the SOI toposheets of scale 1:250000 and 1:50000.
2. Extraction of bands (LISS3 with resolution 23.5 m and PAN with resolution 5.8 m of 1998 and 2002) from the data (in BIL and BSQ format) respectively procured from NRSA.
3. Identification of ground control points (GCP’s) and geo-correction of bands through resampling.
4. Cropping and mosaicing of data corresponding to the study area.
5. Fusion of LISS3 and PAN data using RGB (Red, Green, Blue) to HIS (Hue, Intensity, Saturation) and HIS to RGB conversion technique.
6. Histogram generation, Bi-spectral plots, Regression analysis.
7. Computation and analysis of various vegetation indices.
8. Generation of FCC (False Colour Composite) and identification of training sites on FCC.
9. Collection of attribute information from field corresponding to the chosen training sites using GPS.
10. Classification of remote sensing data (1998 and 2002): Land cover and land use analyses (both district wise and taluk wise).
11. Change detection analysis using different techniques (Image differencing, Image ratioing, etc.).
12. Detection, visualisation and assessment of change analysis.
13. Statistical analysis and report generation.

4 Results and Discussion

Land cover analysis was done by computing Normalized Difference Vegetation Index (NDVI) which shows 46.03 % area under vegetation and 53.98 % area under non-vegetation. Vegetation index differencing technique was used to analyze the amount of change in vegetation (green) versus non-vegetation (non-green) with the two temporal data. 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.

$D_{NDVI} = (IR-R)/(IR+R)\ t_2 - (IR-R)/(IR+R)\ t_1$ ----------equation (1)

t_1 and t_2 in the equation denote the two different dates, where t_1 is for the year 1998 and t_2 for 2002.

The result shows a 16.46 % difference in the vegetation area between the two dates. Figure 3 depicts the image obtained from Vegetation Index Differencing between the two dates (1998 and 2002).

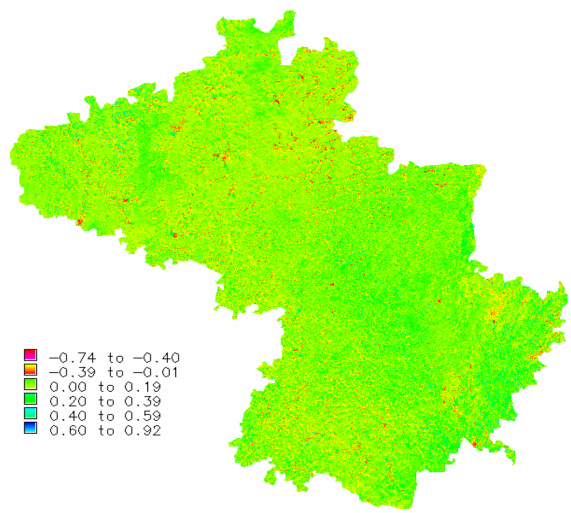

Figure 3: Vegetation Index Differencing

Land use analysis was done by both Supervised classification (accuracy 94.67 %) and unsupervised classification approach (accuracy 78.08 %) using Gaussian Maximum Likelihood Classifier (GMLC) to classify the data in to five categories (agriculture, built-up, forest, plantation and waste land) as depicted in Figure 4.

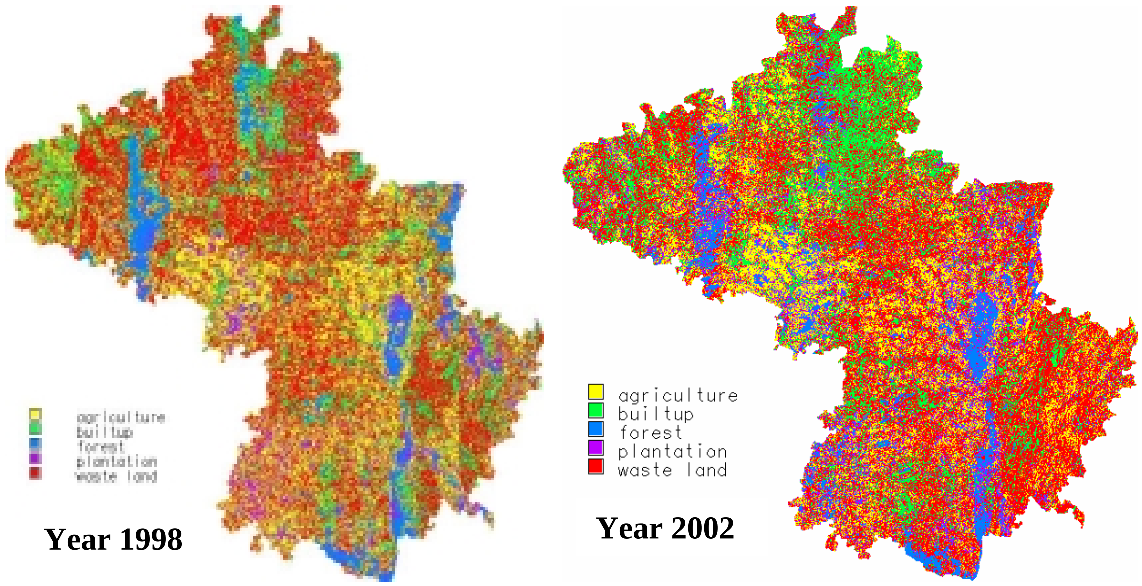

Figure4: Classified image

The Land use analyses as given in table 1, indicates increase of non-vegetation area from 451752 ha. (54.84% in 1998) to 495238 ha (60.17% in 2002). The results also show decrement in forest area and increment in builtup (18.79 %), plantation (12.53 %) and waste land (41.38 %) in 2002 against that in 1998 (builtup-15.96%, plantation-8.53% and waste land-38.88%). Further, taluk wise land use data was extracted by overlaying taluk boundaries and results are tabulated in Table 2.

	1998		**2002**	
Categories	**Area (in ha)**	**Area (%)**	**Area (in ha)**	**Area (%)**
Agriculture	233519	28.34	165711.42	20.13
Builtup	131468	15.96	154668.68	18.79
Forest	68300	8.29	58979.35	7.17
Plantation	70276	8.53	103110.13	12.53
Waste land	320284	38.88	340570.16	41.38

Table 1: Land use details of Kolar district

Taluk	Agriculture (%)		Built up (%)		Forest(%)		Plantation(%)		Waste land (%)	
	1998	2002	1998	2002	1998	2002	1998	2002	1998	2002
Bagepalli	15.75	12.69	22.46	44.65	09.26	03.28	03.65	07.51	48.88	31.86
Bangarpet	27.43	14.15	15.83	09.65	15.95	12.59	13.97	13.32	26.82	50.28
Chikballapur	30.61	30.28	10.56	13.59	18.30	13.35	08.16	15.18	32.37	27.60
Chintamani	29.94	20.07	13.59	20.11	01.95	01.61	05.52	08.52	49.00	49.69
Gauribidanur	22.75	17.24	22.11	23.97	06.50	04.12	02.61	11.57	46.03	43.10
Gudibanda	15.58	22.71	11.04	19.69	04.47	04.67	02.55	09.42	66.36	43.52
Kolar	33.47	21.81	13.09	12.93	05.70	08.62	07.67	14.25	40.07	42.40
Malur	40.95	22.56	08.52	12.84	03.03	09.05	19.62	17.12	27.88	38.42
Mulbagal	22.85	19.26	21.13	12.72	06.25	01.98	09.35	06.58	40.42	59.46
Sidlaghatta	32.47	24.72	13.95	24.76	03.27	07.61	10.75	15.92	39.56	26.98
Srinivaspur	36.52	22.93	15.34	08.04	13.65	12.67	09.34	19.10	25.15	37.25
District	**28.35**	**20.13**	**15.96**	**18.79**	**08.29**	**07.17**	**08.53**	**12.53**	**38.87**	**41.38**

Table 2: Taluk wise land use in percentage area (1998 and 2002)

LISS3 multispectral (MSS) data of the IRS 1C and 1D of resolution-23.5 meters (both 1998 and 2002) were merged with the PAN data of IRS 1C resolution-5.8 meters using the HIS fusion technique for better spatial and spectral resolutions. HIS fusion converts a color image from the RGB (Red, Green, Blue) space into HIS (Hue, Intensity, Saturation) colour space. The intensity (I) component resembles a panchromatic image, and hence is replaced by a panchromatic image of better spatial resolution. A reverse HIS transformation of the panchromatic together with the hue (H) and saturation (S) bands, result in the fused image. Supervised classifications were performed for selected taluks with ground truth data and figure 5 gives the classified image for Chikballapur taluk. The comparative results of the taluks where subtle change detection could be observed in 2002 are as listed in Table 3 and the corresponding taluk wise area in percentage are as listed in Table 4.

Taluk	Agriculture	Built up	Forest	Plantation	Waste land
Chikballapur	19220.54	9293.13	7143.66	9099.19	19064.50
Chintamani	19958.61	19957.48	1488.25	7358.55	40140.64
Gauribidanur	15612.86	19447.85	3310.56	10929.94	39557.35
Gudibanda	5080.74	4662.85	846.32	2738.80	9398.59
Mulbagal	13251.53	10034.88	2578.21	4940.57	51168.42
Sidlaghatta	15872.94	13614.46	5145.42	12425.18	19999.06
Srinivaspur	20189.23	7650.96	11006.07	15490.01	31942.53

Table 3: Talukwise land use area in hectares (ha) of the year 2002

Taluk	Agriculture (%)		Built up (%)		Forest(%)		Plantation(%)		Waste land (%)	
	1998	**2002**	**1998**	**2002**	**1998**	**2002**	**1998**	**2002**	**1998**	**2002**
Chikballapur	32.08	30.12	08.57	14.56	17.55	11.19	10.97	14.26	30.82	29.87
Chintamani	23.45	22.45	12.90	22.45	04.22	01.67	08.13	8.28	51.00	45.15
Gauribidanur	25.46	17.57	21.43	21.89	07.98	03.73	02.77	12.30	42.36	44.52
Gudibanda	16.71	22.36	12.63	20.52	05.25	03.72	03.29	12.05	62.12	41.35
Mulbagal	23.23	16.17	20.68	12.24	06.59	03.15	09.37	06.03	40.13	62.42
Sidlaghatta	30.94	23.67	15.18	20.30	03.12	07.67	09.94	18.53	40.83	29.82
Srinivaspur	33.39	23.40	17.97	08.87	10.29	12.76	09.70	17.95	28.64	37.02

Table 4: Taluk wise land use in percentage area (1998 and 2002)

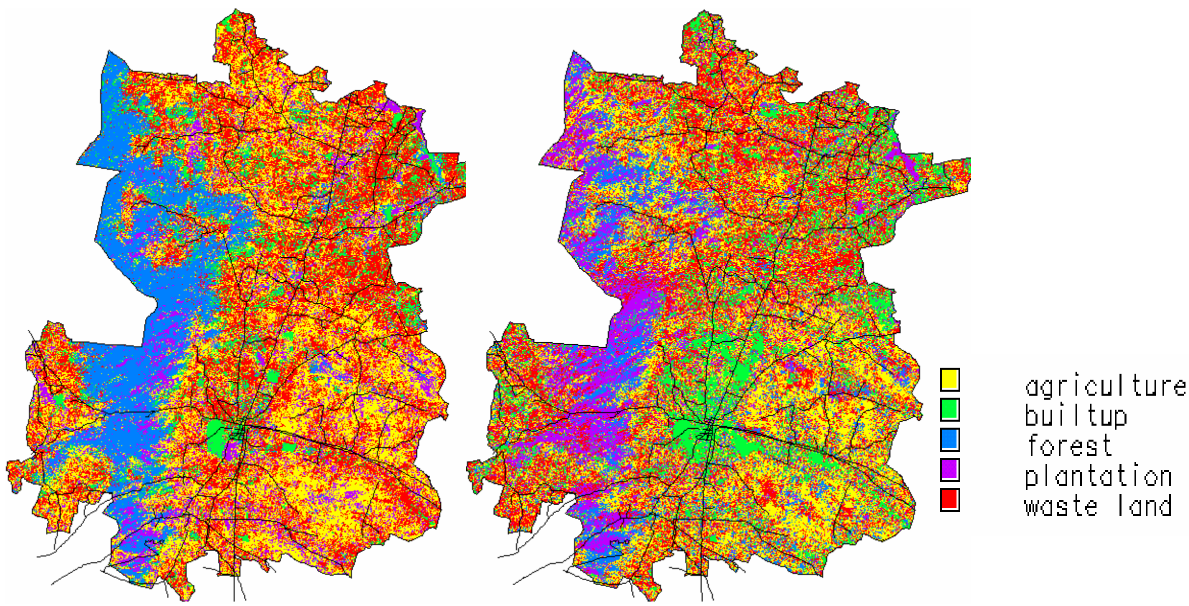

Figure 5: Classified MSS and PAN fused image of Chikballapur taluk (1998 and 2002)

Comparison of the temporal data shows that builtup has considerably increased in Chikballapur (14.56 %) showing urban sprawl in and around the center of the town at the road junction and the forest area has decreased by 6.36%.

5 Change detection techniques

Different change detection techniques such as image differencing, image ratioing, vegetation index differencing and Image regression were attempted to assess the amount of change in the study area.

5.1 Image differencing - Georeferenced images of two different time periods t1 and t2 were subtracted on a band by band and pixel by pixel basis to produce an image which represents the change between the two time periods.

$D_x{}^k{}_{ij} = X^k{}_{ij}(t_2) - X^k{}_{ij}(t_1) + C$ ----------equation (2)

where, $X^k{}_{ij}$ = pixel value for band k and i and j are line and pixel numbers in the image, t_1 = first date and t_2 = second date and C = a constant to produce positive digital numbers.

This technique takes into account the difference of radiance values of pixels between two different dates. Differences in atmospheric condition, differences in sensor calibration, moisture condition, illumination condition also affect the radiance of the pixels. Therefore this technique is better suited to cases as changes in radiance in the object scene is larger compared to changes due to other factors. Frequency analysis of the image show that the pixels with the radiance are found in the tails of the distribution while non-radiance change pixels tend to be grouped around the mean. Figure 6 shows the histogram obtained for the band 4 (near infrared) from image differencing.

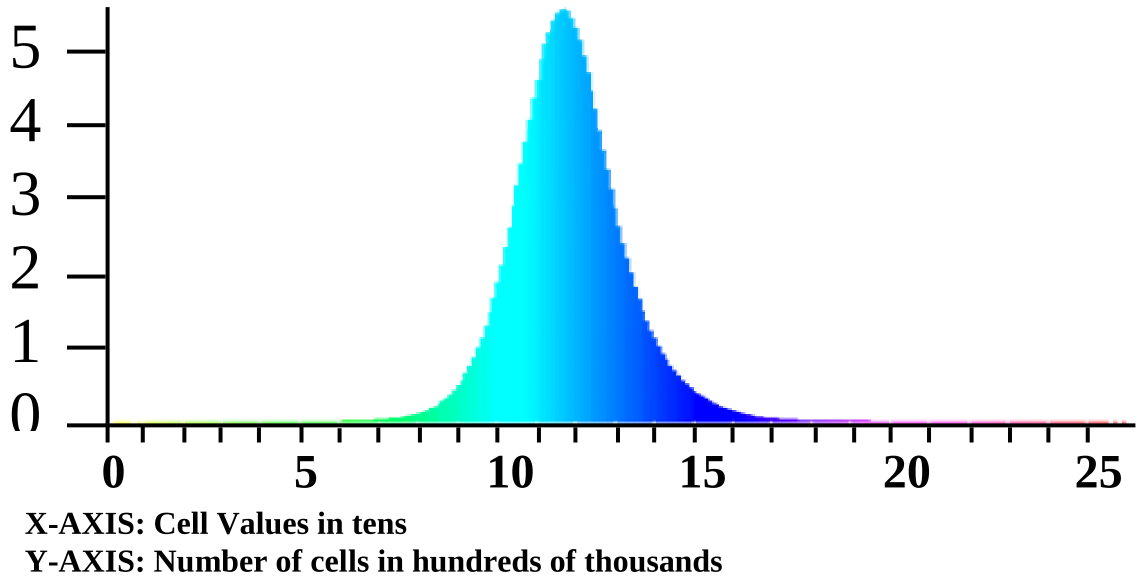

Figure 6: Histogram of the near-infrared band obtained from image differencing

The histogram of the difference image with an ample amount of pixels in the tails clearly indicates changes. However the actual change was unpredictable due to lack of detailed ground truth data pertaining to different categories. The false colour composite (FCC) of the bands obtained by image differencing is depicted in Figure 7, highlighting the changes between the two dates.

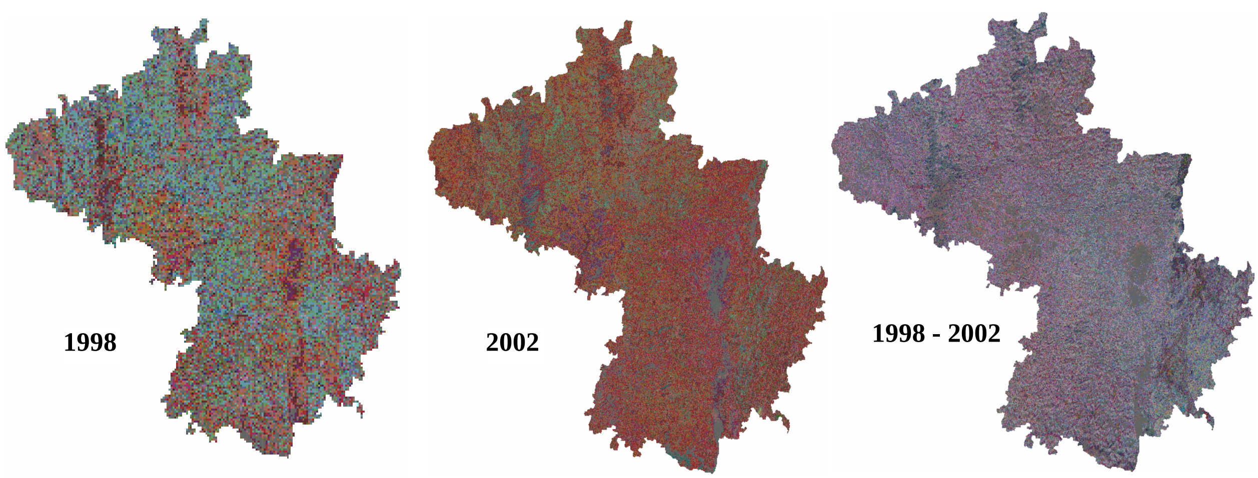

Figure 7: False Colour Composite images

The false colour composite of difference image shows the degradation in area under vegetation (forest, plantation or agriculture), while the unproductive land (barren land) has increased with respect to the time and space.

5.2 Image ratioing – Geocorrected images (G, R and NIR bands) of different dates were ratioed pixel by pixel (band by band) basis.

$$Rx^k_{ij} = X^k_{ij}(t_2) / X^k_{ij}(t_1) \qquad \text{----------equation (3)}$$

Where, $X^k_{ij}(t_2)$ is the pixel value of band k for pixel x at row i and column j at time t_2. If the intensity of reflected energy is nearly the same in each image then $Rx^k_{ij} = 1$ indicating no change.

The ratio value greater than 1 or less than 1 represents a change depending upon the nature of changes occurred between the two dates. Figure 8 shows the histogram obtained for the near infrared band after performing the image ratioing.

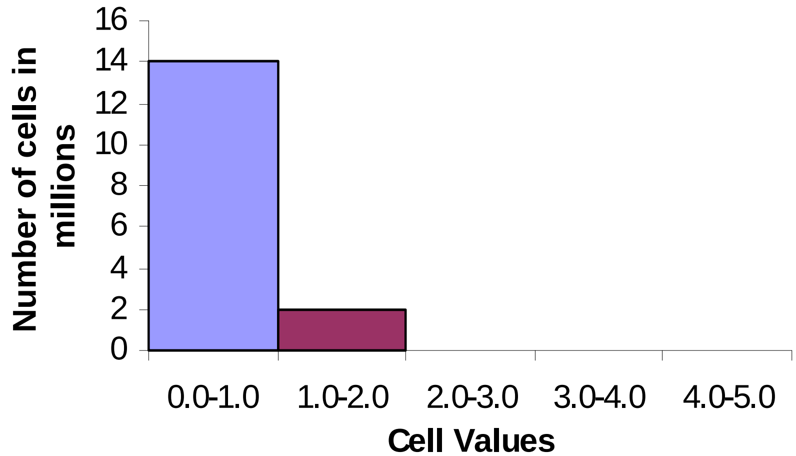

Figure 8: Histogram of the NIR band after temporal date images ratioing

The histogram generated for the different bands showed that a significant part of the image has no change as the number of pixels falling to the category ‘1’ was dominating (with a high peak in the histogram) compared to pixels that had values greater than or less than ‘1’.

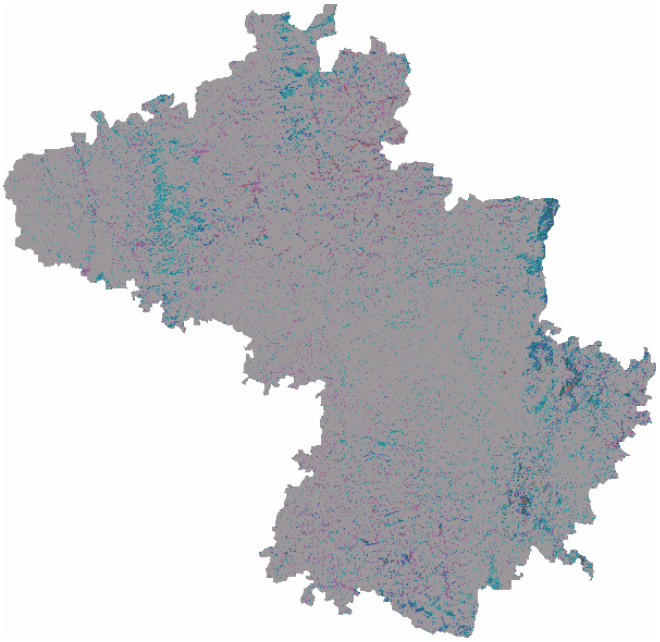

Figure7: False colour composite of the image ratio bands (G, R and NIR)

The false colour composite image obtained after performing the image ratio shows degradation in the forest patches of Chikballapur, Gauribidanur and Srinivaspur taluk, and increase in wasteland. These regions correspond to the values either greater than or less than '1' in the histogram of the ratio image.

5.3 Image regression – It is assumed that pixels from time t_1 are in a linear function of the time t_2 pixels. Using linear regression $X^k_{ij}(t_1)$ was regressed against $X^k ij(t_2)$. It accounts for the differences in the mean and variance between digital number of pixels of different dates in order to reduce the differences in atmosphere condition or Sun angle. The difference image DX^k_{ij} is given with the predicted value $X^{\wedge k}_{ij}(t_2)$, is given by

$$DX^k_{ij} = X^{\wedge k}_{ij}(t_2) - X^k_{ij}(t_1) \qquad \text{----------equation (4)}$$

Regression analysis was performed for each band (Green, Red and Near-infrared of 1998 and 2002) and the results are listed in Table 5.

X (1998) (Independent variable)	Y (2002) (dependent variable)	S	I	r	R	P (Significant value)	DN (Digital number)	D (difference)
Band2	Band2	-0.43	149.62	-0.636	0.404	< 0.011	128	-33.42
Band3	Band3	-0.55	151.80	-0.694	0.482	< 0.004	117	-29.55
Band4	Band4	-0.67	172.17	-0.546	0.298	< 0.035	111	-13.20

Table 5: Image regression results

S = slope, I = intercept obtained from linear regression, r = the correlation coefficient, R = coefficient of determination, P = significant value or significance level, DN = digital number of the pixel that was chosen from the set of numbers in the bands and D = the predicted value that would be obtained from *equation 4*.

In this method the mean and variance of the pixels takes care of environmental interferences like adverse effects from atmospheric condition and sun angle by distributing these variations to all the pixels. Thus the differences obtained in this analysis is minimal when compared to other methods.

6 Conclusion

Holistic decisions and scientific approaches are required for sustainable development of the region. Change detection techniques using temporal remote sensing data provide detailed information for detecting and assessing land cover and land use dynamics. Different change detection techniques were applied to monitor the changes. The change analysis based on two dates, spanning over a period of four years using supervised classification, showed an increasing trend (2.5 %) in unproductive waste land and decline in spatial extent of vegetated areas (5.33 %). Depletion of water bodies and large extent of barren land in the district is mainly due to lack of integrated watershed approaches and mismanagement of natural resources.

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References

1. Dai, X.L., and Khorram, S., Remotely Sensed Change detection based on Artificial Neural Networks. *Photogrammetric Engineering & Remote Sensing*, 65(10), pages 1187-1194, 1999.

2. Macleod, R.D., and Congalton, R.G., A quantitative comparison of change detection algorithms for monitoring eelgrass from remotely sensed data. Photogrammetric Engineering & Remote Sensing, 64, pages 207-216, 1998.

3. Mitra, D., Change detection using remote sensing data in a coastal environment. *Trends in Geoinformatics Technology and Applications,* pages 107-112, 1999.

4. Prenzel, B., and Treitz, P., Remote sensing change detection for a watershed in north Sulawesi, Indonesia. *Progress in Planning*, 61, pages 349-363, 2004.

5. Xavier, B., and Gerard, S., LUCC data requirements workshop. *Survey of needs, gaps and priorities on data for land-use/land-cover change research*, Barcelona, Spain, LUCC Report Series No. 3, 1997.