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Change Assessment of Urban Green Spaces of Dehradun City Using Image Derived Parameters

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Abstract

Mapping and monitoring of urban green spaces is a prerequisite for effective management and protection of urban living environment. Fast growth of settlements and consequent ecological problems in urban zones necessitates application of advanced technologies like Remote Sensing to obtain detailed, upto date and accurate information about land use/land cover (LU/LC) status for management and planning of urban growth. This paper attempts to investigate the LU/LC changes in Dehradun city and associated changes in urban green cover over the period from 2004 to 2009. IRS P6 (LISS-IV) datasets of year 2004 and 2009 have been used. LU/LC of both years has been delineated using Maximum Likelihood Supervised classification technique. Classified maps were crossed to generate an urban green cover change map. Normalized Difference Vegetation Index (NDVI) has been employed for detection of change areas and quantification of the amount of decline or increase in urban greenery. Results reveal that over the period of five years a significant decline has occurred in the extent of urban green spaces in Dehradun city with concomitant fragmentation resulting in considerable degradation of urban environment especially in southern parts of the city.

Keywords: *Remote Sensing, Change Detection, Land cover, Urban Green Space, IRS-P6 LISS-IV*

Introduction

Green areas are vital in determining the quality of urban environment. Trees play an important role in cleaning pollution, equilibration of water cycle and stabilizing the urban micro-climate. They influence physical health of citizens – parks are used as recreational areas. In the process of land use planning for almost all cities allocation of urban land to green spaces is an important policy issue. More specifically, urban green spaces as a class of land use is defined as places within the extent of an urban area that provide opportunities for outdoor recreation and enjoyment or simply pockets of vegetation in the city environment (Beer et al., 1997). Areas such as parks, green ways, residential landscaping and unutilized fields may serve as urban green space.

Urbanization is one of the most important factors that changes land surface leading to modification of receiving environments which are usually composed of natural cover. This phenomenon, both in population and spatial extent, transforms the landscape from the natural cover types to impervious urban lands (Xian et al., 2005). The pressure for additional housing and business demands in towns and urban areas alters existing urban green spaces even more in the route to development (The World Resources Institute, 1996). The information on these changes is of great use to land managers and policy makers in order to make informed and judicious decisions that effectively balance the positive aspect of development and its negative impact on the receiving environment.

The management of vegetated areas by urban planners relies on detailed and updated knowledge of their nature and distribution. Ground survey mapping provides outputs of high accuracy and detail (Mathieu et al., 2005) but it is very time consuming and in some cases such detailed information is not called for. The use of remote sensing data in recent times has been of immense help in monitoring the changing pattern of vegetation. Using remote sensing and image processing techniques vegetation condition can be assessed and monitored at a range of scales from site specific to regional or even larger, depending on one's goals (Briggs and Freudenberger, 2006). 'Change detection' in remote sensing image analysis is a process which observes the differences of an object or phenomenon at different times (Singh, 1989) and quantifies the change through analysis of variation in spectral response of vegetation or other cover type which occurs at a given location.

In 2001 urban population of Dehradun city was 4.5 lakhs which accounted for 34.92 percent of total population of Dehradun district and 31.09 percent of the total urban population of Uttarakhand state. After creation of Uttarakhand state, Dehradun city was designated as the state capital which ushered an era of rapid expansion and densification of built up area within municipal area. There has been a remarkable acceleration in construction activities for industries, institutional infrastructure and residential colonies etc. Along with physical expansion of the city, extensive destruction of urban green spaces has occurred which conflicts with an environmentally sound developing paradigm.

Little research has been carried out till now to explore the changes in urban green spaces and other land cover (LC) types of Dehradun city during the past decade. The purpose of this study is to identify changes in the urban green spaces of Dehradun city and to determine the spatial patterns and trends of changes over the period of five years from 2004 to 2009 using remote sensing image analysis and change detection techniques. The information will help to identify priority areas for preservation of green areas of the city.

Study Area and Data Used

Dehradun city is the largest city of the hilly region of Uttarakhand extending between 77°58´55º E and 78°06´22º E longitude and from 30°16´13º N to 30°24´16º N latitude. It is well connected by rail and road transport to Delhi, Saharanpur, Haridwar, Mussoorie, Chakrata etc. and two state highways no. 54 and no. 49 pass through it. Dehradun city along with its contiguous outgrowth forms an "Urban Agglomeration" consisting of Dehradun municipal area, Forest Research Institute, Adhoiwala growth, Dehradun Cantonment, Clement Town Cantonment and Raipur Town.

The study deals with the municipal area of the city (Fig. 1 see page 71) which has witnessed rapid urbanization during the preceding decade characterized by fast spatial expansion along with an accelerated population growth. It presently spreads over an area of 66.21 square km comprising of 60 wards. In 2001 the municipal area was 52 square km which has increased by 14.21 square km (27.37 percent) within a decade. The population of the city was 4.5 lakhs in

2001 (Census, 2001) which has doubled over the decade with current population at about 9.65 lakhs (Census, 2011).

High resolution satellite datasets at spatial resolution less than 6 m, viz. IRS-P6 LISS IV images, providing information in multispectral mode are very good sources for urban vegetation mapping at the level of detail optimum for urban mapping. Spectral information in near infrared (NIR) band offered by these images is pre-requisite for every vegetation analysis. Accordingly the study has been accomplished using a set of cloud-free IRS–P6 LISS IV imagery acquired on 11th April, 2004 and 20th June, 2009 (henceforth referred to as LISS 2004 and LISS 2009 respectively). LISS IV datasets contain spectral information in three bands - Near infrared (NIR), Red (R) and Green (G), at a spatial resolution of 5.8 m. Each scene covered approximately 66.21 km^2 comprising Dehradun city and its outskirts. Since both images have been acquired in summer they represent identical vegetation condition of green areas in the city. Topographic maps of Dehradun city (Toposheet no. 53 F/15 & 53 J/3) at 1:50000 scale acquired from Survey of India have been used for geometric correction of images. Field data have been collected for identifying sample sites for classification and reference data for accuracy assessment of classified images.

Methodology

Fig.2 succinctly illustrates the methodological workflow of the study. The analysis has primarily been carried out in four broad steps:

Image pre-processing.

Normalized Difference Vegetation Index (NDVI) image generation and differencing.

Image classification and post-classification change detection.

Analysis of results and identification of spatio-temporal change of urban green spaces.

Erdas Imagine version 9.1 has been used for image processing tasks and generation of vector layers has been performed in ArcGIS version 9.2.

Image Pre-processing

For quantitative analysis based on radiometric information such as NDVI differencing, the images should be corrected radiometrically to compensate for radiometric divergence (Mass, 1999). Without radiometric calibration of multi-temporal dataset false changes can occur in the classified maps. Relative radiometric correction has been performed using dark and bright pixel control set (after Hall et al., 1991) on each of the R and NIR bands of LISS 2004 with reference to LISS 2009. Radiometrically corrected LISS 2004 has been rectified using topographic map of Dehradun as reference and projected to UTM projection with spheroid and datum WGS 84 N and zone 44 with a total Root Mean Square Error (RMSE) of 0.57 pixels. Radiometrically corrected LISS 2009 has been co-registered to geometrically rectified LISS 2004 using 13 GCPs with a total RMSE of 0.21 pixels. Resampling has been done using Nearest Neighbor method so as to retain the original radiometry of the datasets. Ward map of the city in vector format has been generated using on-screen interpretation and digitization and municipal boundary used to extract the study area from both the images.

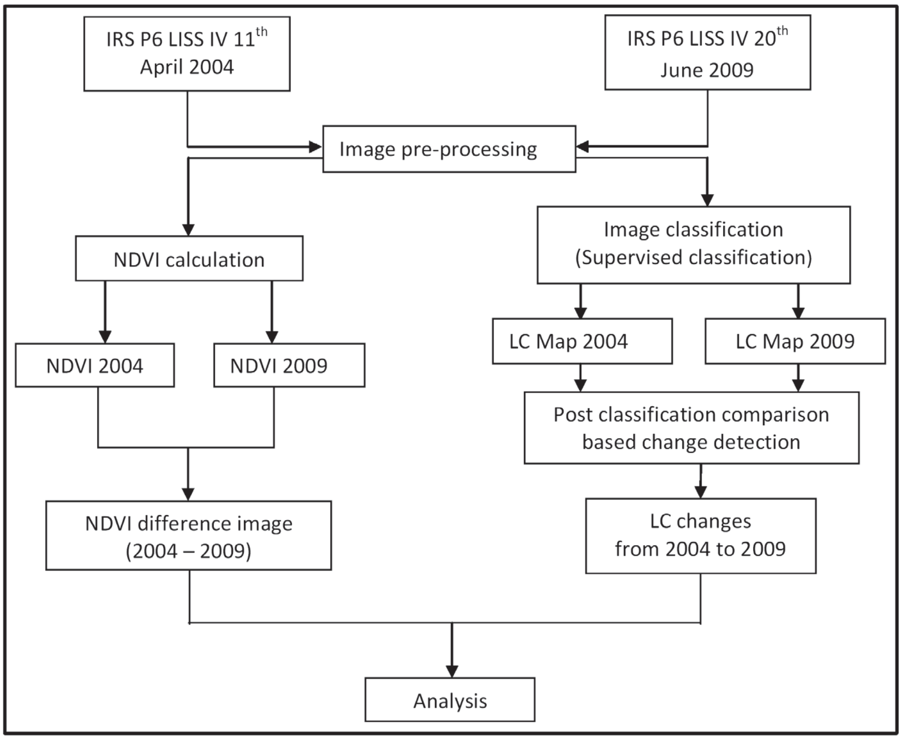

Fig. 2

Normalized Difference Vegetation Index (NDVI) Image Generation and Differencing

Remote sensing data can provide information on vegetation structure and amount of biomass and leaf area as vegetation cover can be estimated through various indices (Purevdorj et al., 1998). Normalized Difference Vegetation Index (NDVI) is one of the most widely used vegetation indices among other methods which have been reliable in monitoring vegetation change.

NDVI is related to the absorption of photosynthetically active radiation and basically measures the photosynthetic capability of leaves which is related to vegetative canopy resistance and water vapor transfer (Malo and Nicholson, 1990). NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portion of the electromagnetic spectrum due to absorption by chlorophyll and other pigments and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of green leaf (Campbell, 1987). NDVI values range from -1 to +1. Because of high reflectance in the NIR portion of the electromagnetic spectrum healthy vegetation is represented by high NDVI values between 0.1 and 1. Conversely, non- vegetated surfaces yield negative values of NDVI.

NDVI has been calculated as the ratio of R and NIR bands of each of the images individually as per the equation given below. This produced an NDVI image for 2004 and 2009 each, henceforth referred to as NDVI 2004 and NDVI 2009 respectively.

$$\text{NDVI} = \frac{(\text{NIR-R})}{(\text{NIR+R})} \quad \text{or}$$

$$\text{LISS IV NDVI} = \frac{(\text{BAND4-BAND3})}{(\text{BAND4+BAND3})}$$

NDVI difference image has been produced by subtracting NDVI 2009 from NDVI 2004. In the difference image zero values indicate no change areas, negative values represent decrease in vegetation and positive values indicate increase in vegetation. However slight changes in the brightness values between the two dates may be attributed to noises even after radiometric normalization.

To avoid inflated change assessment based on change values ascribable to radiometric noise optimum high-end and low-end threshold change values have been identified. Threshold values have been set up equidistant to the mean of Brightness Values (BV) of NDVI difference image in each tail using NDVI difference image histogram. Optimum low-end threshold value has been determined at difference value of -0.183857 corresponding to 11 percent decline in BV between the two dates and high-end threshold has been determined at 0.731959 representing 41 percent increase in BV in 2009 as compared to 2004. Subsequently NDVI difference image has been classified into three classes: (1) vegetation decline if a pixel value was lower than the low-end threshold, (2) vegetation increase if a pixel value was higher than the high-end threshold, and (3) no change if pixel value lays between the two thresholds.

Image Classification and Post-Classification Change Detection

Supervised classification using Maximum Likelihood Classifier has been performed on both the datasets to map an aggregate land cover of the study area during both the years. Both the images have been classified into five classes- built up, agriculture, urban green spaces, water/river bed and fallow land. Accuracy assessment has been performed for each classified image using 160 reference pixels identified through stratified random sampling. Thereafter the classified images have been compared visually as well as quantitatively to detect and measure the pattern and magnitude of changes in selected land cover categories especially the urban green spaces which have occurred in 2009 as compared to 2004.

Results and Discussion

NDVI change has been given in Table 3. NDVI change detection reveals that during 2004 -2009 there has been a significant reduction in vegetation as a whole which amounts to approximately 14.37 square km. Nevertheless, an increase has also been observed in a few areas covering approximately 3.57 square km.

Large patches of negative changes are well distributed in the southern part of the city along the Haridwar byepass road and national highway no 7. Positive changes are confined to mainly the institutional areas, cantonment and new planned areas which may be attributed to plantation activities.

Classified maps of Dehradun city for 2004 and 2009 have been illustrated in Fig.3 (see page 72) and class-wise accuracy assessment of the maps has been given in Table 1. Spatial distribution of various land cover classes in terms of their extent in both years has been given in Table 2. An overall accuracy of 84.38 percent with an overall kappa of 0.79 has been achieved for 2004 and 87.50 percent overall accuracy

Table - 1 : Accuracy assessment statistics of classified maps.

Classified map	User Accuracy (%)	Producer Accuracy (%)
2004		
Built up	87.90	89.23
Agriculture	86.36	95.00
Urban green spaces	100.00	85.00
Water / River bed	100.00	96.00
Fallow Land	80.95	94.44
	Overall Accuracy = 84.38% Kappa Statistics = 0.7912	
2009		
Built up	93.59	94.81
Agriculture	97.78	86.67
Urban Green spaces	97.78	86.27
Water / Riverbed	100	100
Fallow Land	72.73	66.67
	Overall Accuracy = 87.50% Kappa Statistics = 0.8097	

with 0.81 overall kappa has been achieved for the classified map of 2009. Urban green space has been classified with user accuracy (UA) and producer accuracy (PA) higher than 85 percent for both the years with UA greater than 95 percent for both 2004 and 2009. Similarly high UA and PA of more than 85 percent has been achieved for both built up and agriculture class for both the years.

Classified maps corroborate the observations of NDVI change map while revealing the spatial patterns of class to class changes. Specific parts of the city have undergone notable land cover changes over five years. Consequent upon rapid population growth in the study area increased demand for built up has taken significant toll on urban green spaces. Spatial expansion of settlement has mostly occurred in the outer periphery. Maximum negative change in vegetation can be observed in the southern part of the city. In 2004 thick patches of trees populated the road sides. In 2009 these have been replaced by built up which increased significantly and become a dominant class. Further agriculture formed the predominant class in this area in 2004. The agricultural cover has considerably been replaced by rapid expansion of built up in five years. Besides decline in gross amount of vegetation contiguous outgrowth of built up area has also led to fragmentation of previously continuous green space cover.

Quantitatively there has been a striking decline of 5.2 square km. in the extent of urban green spaces due to urban development in the city as a whole. In total an increase of 6.76 square km. has been recorded in built up which amounts to 10.21 percent of the total city area. Major part of it has been at the cost of urban green spaces. Fallow land has recorded an increase of 2.4 square km. Agriculture and water/river bed have declined by 3.79 square km. and 0.17 square km. respectively.

Table - 2 : Spatial extent of selected land cover classes in Dehradun city (2004 & 2009)

Class	**2004**		**2009**		**% change 2004 to2009**
	Area (km²)	**% of total area**	**Area (km²)**	**% of total area**	
Built Up	26.96	40.71	33.72	50.92	10.21 (+)
Agriculture	14.63	22.09	10.84	16.37	05.72 (-)
Urban Green Spaces *	15.22	22.98	10.02	15.13	07.85 (-)
Water/River bed	01.30	01.96	01.13	01.70	00.26 (-)
Fallow Land	08.10	12.23	10.50	15.85	03.62 (+)
Total Area	66.21	100.0	66.21	100.0	

*Includes open spaces, recreation spaces, urban forests and sports grounds etc.

Note: Positive and negative signs in parentheses denote positive and negative change in 2009 as compared to 2004 respectively.

Four major urban green space cover transitions can be observed during the period – (1) conversion of road side vegetation into built up along major roads, such as highways, which have also been the major routes of urban expansion; (2) conversion of agricultural land into built up mainly in city outskirts; (2) densification of built up areas in core areas of the city at the cost of urban green spaces, and; (4) increase in urban green spaces because of plantation. Fig. 4 (a) and box A in Fig. 3 show the urban expansion along the newly constructed Haridwar bypass road which came into existence after year 2000. This has resulted in massive clearing of road side vegetation.

Fig. 4 (b) and box B in Fig. 3 show encroachment of built up on agricultural land. Trees on agriculture land finished off due to newly constructed colonies. Built up has increased in the core area too to cater to the needs of increasing population. Fig. 4 (c) and box C in Fig. 3 show densification of built up in central part of the city in areas along Bindal river. Part of this development has taken place at the cost of urban green space, some has occupied the fallow and vacant land. Fig. 4 (d) and box D in Fig.3 show an increase in urban green space in a few patches owing to plantation activities in areas around Forest Research Institute.

Conclusion

Designation of Dehradun city as the state capital has ushered an era of rapid urbanization in the region in the last decade resulting in densification as well as expansion of built up area to cater to the needs of increasing population. Increase in urban built up area has primarily been at the cost of urban green spaces and agricultural land which has adversely affected the quality of urban environment. Major negative changes in vegetation are confined to the peripheral parts of the city and major

Table 3. NDVI Change Map

S.NO	NDVI CHANGE MAP	AREA (km^2)
1.	Negative Change	14.37
2.	Positive Change	03.57
3.	No change	48.27
Total	66.21	

transportation routes which are also the main routes of urban expansion in the region. Decline in total area of urban green spaces of the city has also been accompanied by fragmentation of continuous patches. Satellite image based indices and classified products can be instrumental in monitoring the patterns and trends of urban growth, quantifying urban land cover changes, identifying problem/ priority areas and devising ecologically sound development policies.

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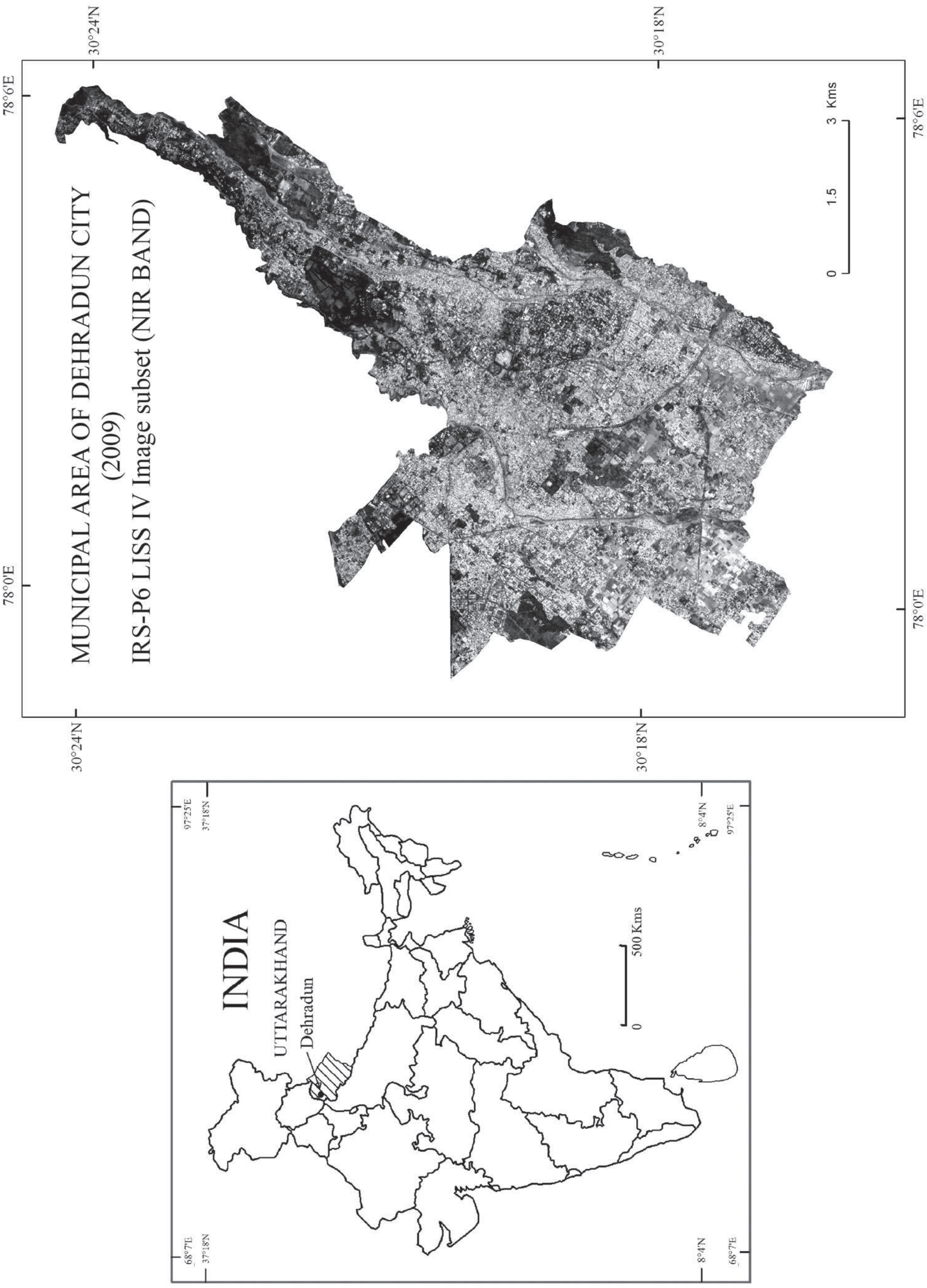

Fig. 1 See page 64 for text

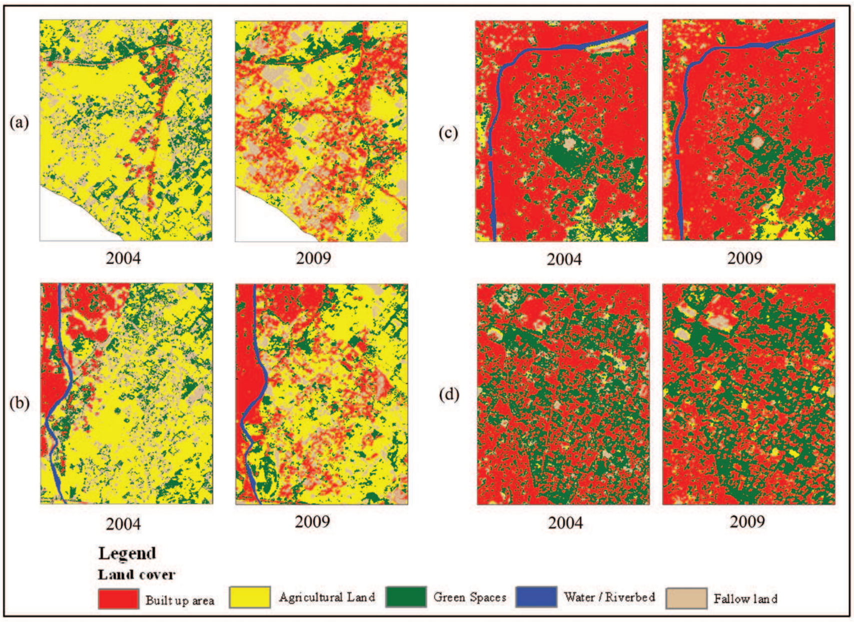

Fig. 3 See page 67 for text

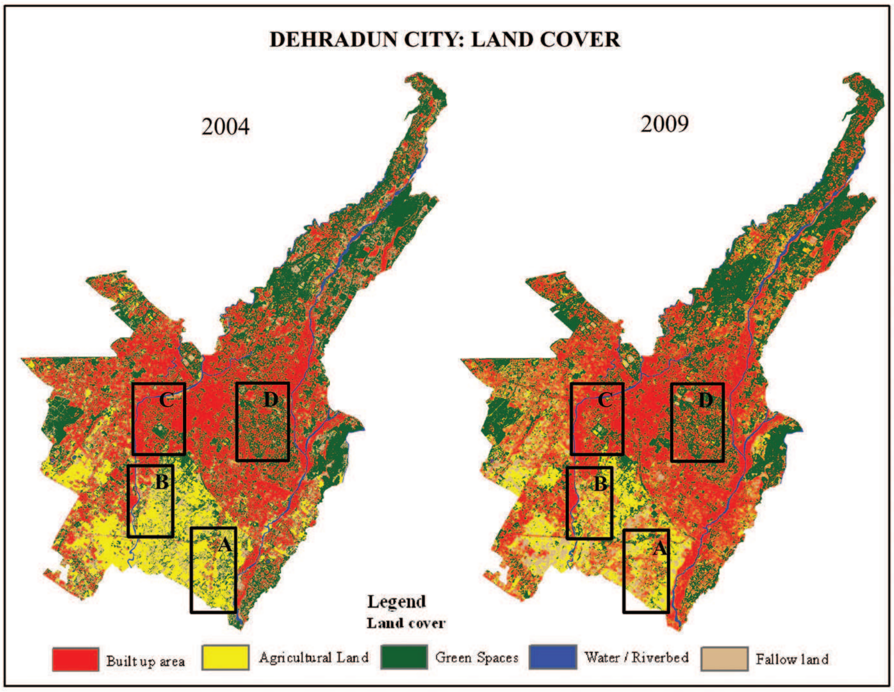

Fig. 4 See page 69 for text

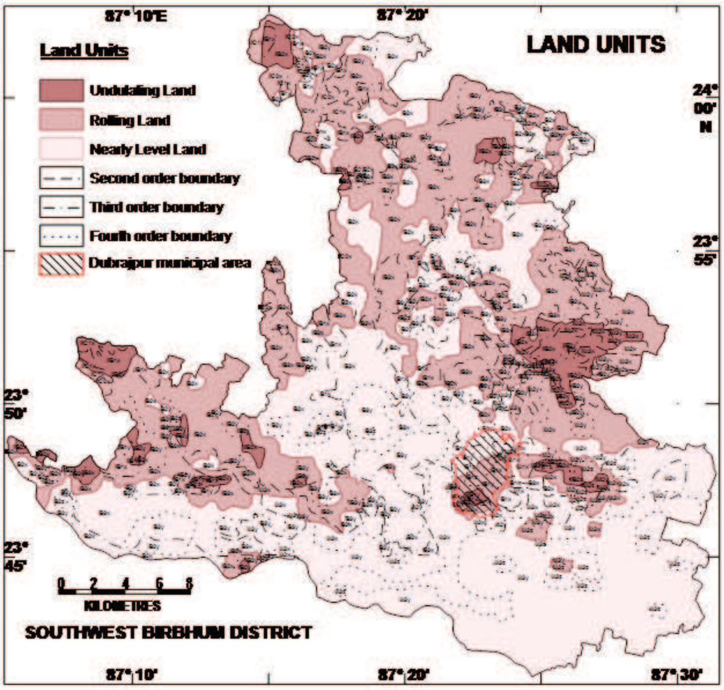

Fig. 3a See page 78 for text

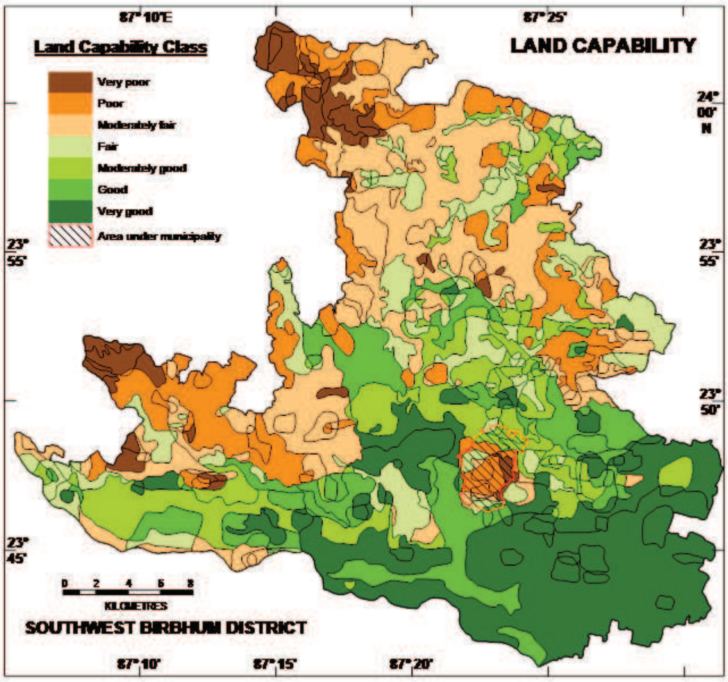

Fig. 5 See page 82 for text

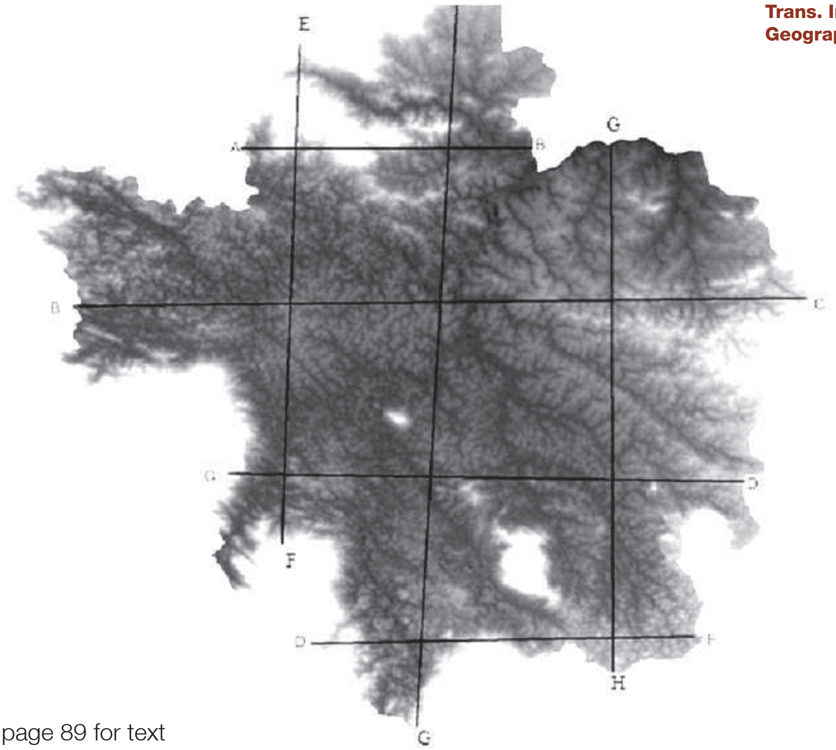

Fig. 2 See page 89 for text

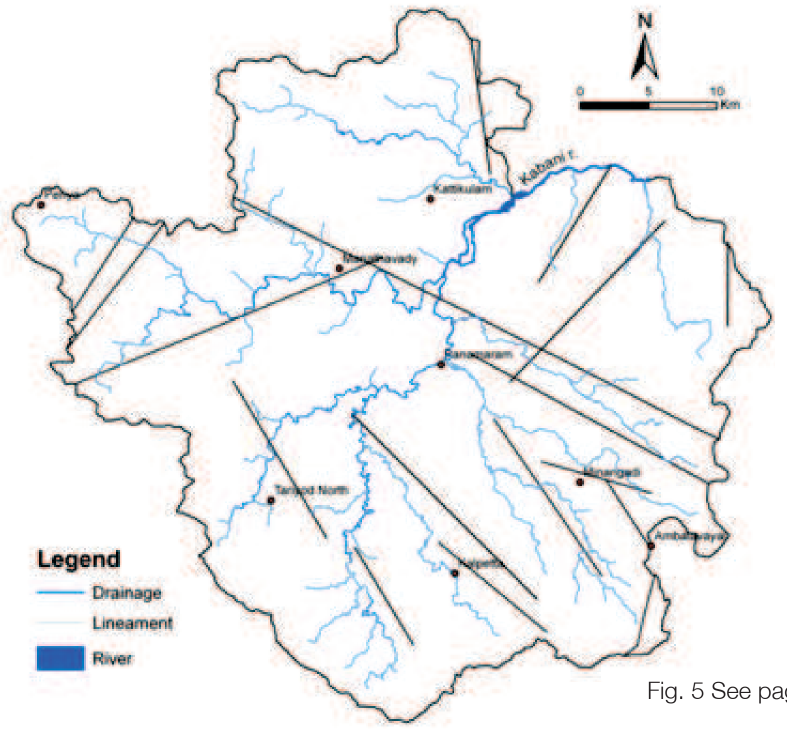

Fig. 5 See page 94 for text