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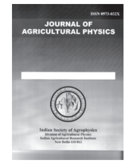

**Research Article**

# Land Use / Land Cover Mapping Using High Resolution Mutlispectral Satellite Data

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**ABSTRACT**

High resolution satellite data are a potential source for mapping and updating land use and land cover at a finer scale. In the present study, an attempt has been made for land use/ land cover mapping of Dehradun city using very high resolution IKONOS satellite multispectral (4m) and PAN (1m) along with LISS III (23.5 m) and Pan (5.8m) data of IRS 1D. Entire city was broadly classified into seven land use/land cover classes using supervised maximum likelihood classifier technique. Study revealed a great potential of multispectral high resolution IKONOS data as an alternate for updating and maintaining cartographic and geographic databases. Moreover, high spatial resolution sensor can be very informative for level II and III land use/land cover classification. Advanced sensors like IKONOS with a spatial resolution of 4 m even in multispectral mode, could be very useful to map the urban areas at a spatial scale, which was previously no possible with the satellite imagery.

**Key words:** IKONOS, Land use/Land cover, Dehradun city

## Introduction

Land is the sole source of sustenance of mankind supporting plants and animals on it. The growing population coupled with increasing demand on land resource has brought in extra pressure on the already depleting resources all over the country. Thus, land cover/land use identification and mapping has become a critical basis for efficient land management and planning viz., prediction of land use changes, prevention of natural disaster, management and plan of land use and protection of environment. With further development of remote sensing technology, monitoring the status and changes in land use / land cover is getting rapid, credible and effective. Over the years, remote sensing has been used for land use/land cover mapping in different parts of the country (Gautam and Narayan, 1983; Jain, 1992; Minakshi and Sharma, 1999; Brahmabhatt *et al*., 2000; Vijay Kumar *et al*., 2004). Pua *et al.* (2011) suggested the use of region-based classification techniques, using an image object (IO) rather than a pixel as a classification unit, and examined the improvement of the classification accuracy in urban land cover mapping using IKONOS high spatial resolution imagery. They explored the performance of artificial neural network (ANN) and minimum distance classifier (MDC) in urban detail land cover classification. Detection of discrepancies in

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land use classification using high resolution optical IKONOS satellite data based on interactive discriminate analysis was also investigated by others (Gilichinsky and Peled, 2014).

The field of remote sensing has made tremendous progress over the last decade with a variety of sensors delivering high resolution data on operational basis. However, a majority of applications still depend on image processing concepts conceived and developed during early 70's through classification of single pixel in a multi-dimensional feature space. The objective of satellite image processing for planning is fundamentally the land use/cover classification of an area. The traditional method is expensive and time consuming. High-resolution satellite data could be an alternative for updating and maintaining cartographic and geographic databases of land use of a region. Advanced sensors like IKONOS with a spatial resolution of less than 5 m even in multispectral mode, offers the potential to map the urban areas at a spatial scale which is otherwise not possible with the conventional satellite imageries.

In this study, we have used high resolution IKONOS data to map the land use/cover of the Dehradun city. The emphasis was mainly on urban area classification. However, the ward-wise statistics for each land use class were also obtained using the census data of the year 1991. In the year 1991, there were 34 wards in the entire city, and the area under each class was calculated for each ward and presented.

## Materials and Methods

### *Study area*

Dehradun, the state Capital of the newly formed Uttaranchal State lies in the Doon valley between 77°30′ to 78°00′ longitude and 30°15′ to 30°25′ latitude. It is surrounded by river Song on the east and river Tons on the west, Himalayan ranges with the Queen of Hill Stations Mussoorie overlooking from North, and Sal forest in South. The total area is 6423 ha. The city is located at an altitude of 640 m above mean sea level. The lowest altitude is 500 m on the southern part and 1000 m on the northern part which clearly indicates that the city slopes gently from north to south and southwest with a gradient of 1:37.5. The climate of Dehradun is salubrious and humid tropical monsoonal. The rivers Rispana and Bindal drain through the city. The alluvial soils deposited by the streams make the region very fertile.

### *Satellite data analysis*

The details of satellite data used in the study is given in the Table 1. Apart from the satellite data, other collateral data were used in the study *viz*., (i) Guide Map of the city (1:20000 scale, surveyed in 1965-68, published in 1980), (ii) Ward Map on scale of 1:20000 and (iii) Survey of India toposheet of 1:50000 scale. The image processing software, ERDAS IMAGINE was used for processing the satellite imagery using toposheets and the guide map for classification purpose. Digitization of the boundary map of the city and the ward boundaries was done in ArcGIS platform. ArcGIS was also used for further map conversion and overlay analysis.

The methodology adopted for the present study is shown in Fig. 1. Maps were scanned and converted to raster digital format, georeferenced and projected. The classified land use/land cover map was also georeferenced. All the satellite images were georectified. Merging the panchromatic IKONOS data of 1 m resolution with multispectral imagery of 4 m resolution was performed by using multiplicative technique; a simple multiplicative algorithm resulted in arithmetic integration of two raster images. Nearest neighbour option technique was used to resample the multispectral input to that of the high resolution image so that spectral information is not lost. Standard False Colour Composite

**Table 1.** Satellite data used in the study

| Satellite(s) | Acquisition date | Sensor | Spatial resolution (m) |
|---|---|---|---|
| IKONOS | 19-4-2001 | Multi-spectral | 4 |
| IKONOS | 19-4-2001 | PAN | 1 |
| IRS ID | 11-4-2000 | LISS III | 23.5 |

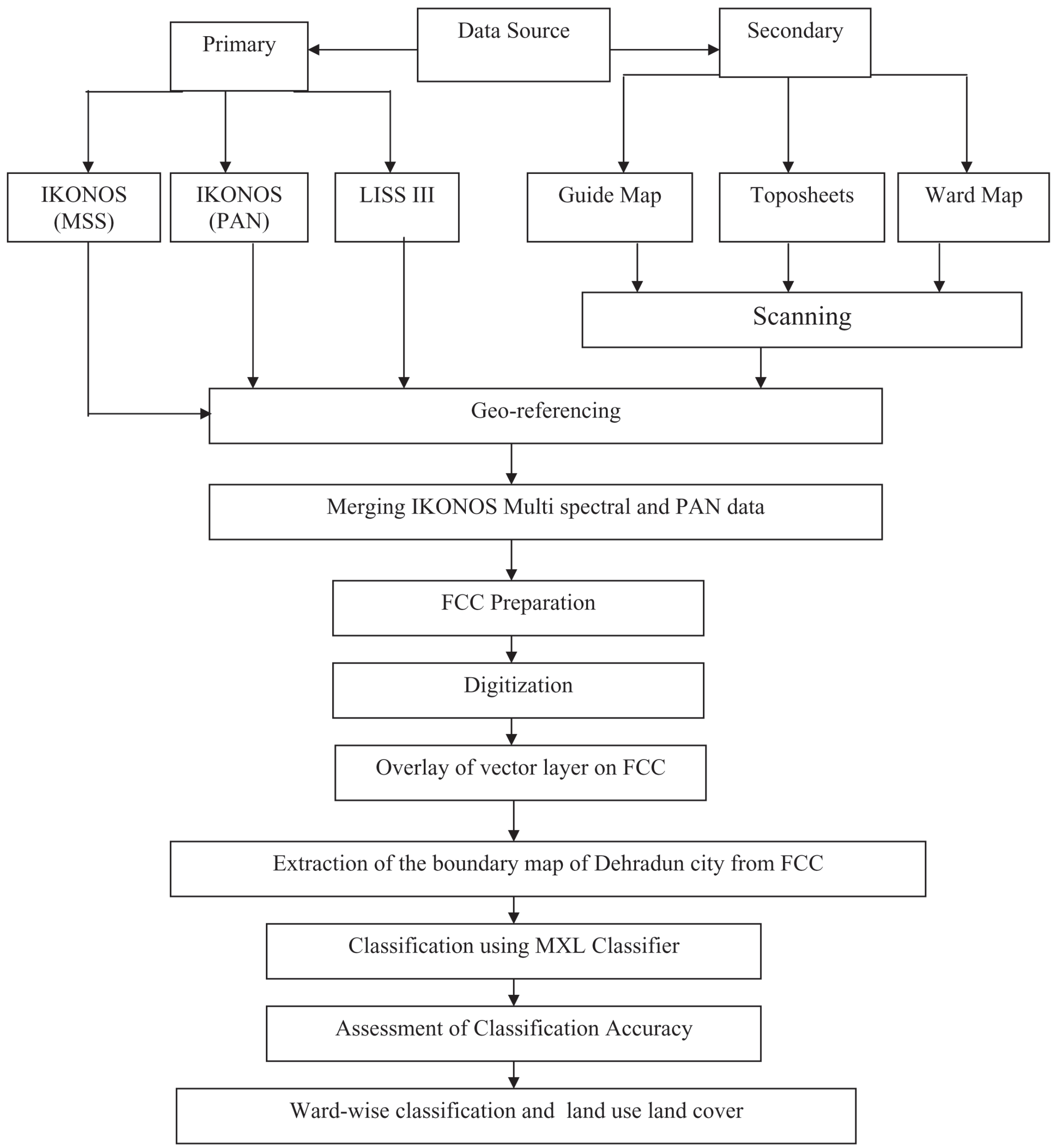


**Fig.1.** Flow chart depicting the procedure of land use/ cover mapping of Dehradun district using high resolution IKONOS data

(FCC) was generated taking combination of green (B2), red (B3) and infrared (B4) bands from IRS-1D, LISS-III and multispectral IKONOS image.

The boundary map of the city was digitized using the IKONOS image. The ward boundaries were digitized using the IKONOS image together with the ammonia print of ward boundary map. The ward boundaries had 34 wards (Municipal Corporation of Dehradun). The map was masked and extracted from the image.

A reconnaissance survey has been carried out in the study area to mark all the major road

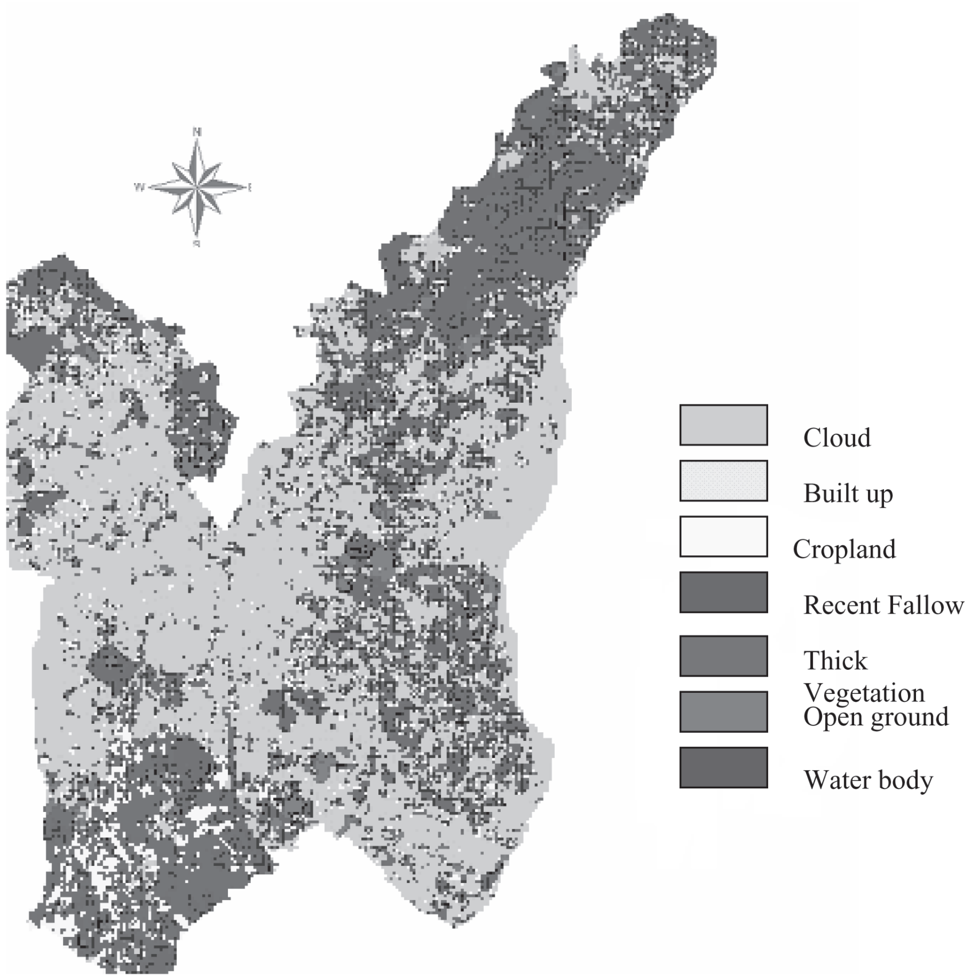


**Fig. 2.** Classified IKONOS image of Dehradun

networks, commercial, institutional and major industrial areas, parks, and gardens. Field verification was carried out to check the accuracy of interpretation while the unclear/doubtful classification according to the master plan was verified. The ground truth was collected for different sites on the basis of toposheet, guide map and merged IKONOS Multispectral and PAN imageries. The training areas were identified and a numerical description of the spectral attributes of each land cover type was developed. On-screen digitization was done to obtain training sample data by digitizing outline of training areas on the FCC displayed over screen using a reference cursor. Through signature comparison, the spectral separability between different signature classes was studied. The method of maximum likelihood (MXL) classification has been followed for the classification purpose in this study. Besides this, ward-wise classification was has also been done followed by accuracy assessment through Kappa statistics.

## Results and Discussion

A broad land use/land cover map was prepared using IKONOS data and IRS ID LISS III data for April 19, 2001 and November 3, 2000, respectively. Fig. 2 shows the classified image of IKONOS. Digital interpretation techniques were used for interpretation of the satellite data. The land use of the study area was classified into five broad classes using MXL supervised classification techniques. The predominant land use of the city is the built up land with an area of 15124864 $m^2$ which accounts to 52.7% of the total area of the city (Table 2). The built up area comprises of

**Table 2.** Land use/cover classification of Dehradun city

| No. | Classes | Area in sq mts | % area |
|---|---|---|---|
| 1 | Cloud | 256 | — |
| 2 | Built up | 15124864 | 52.67 |
| 3 | Cropland | 2435312 | 9.27 |
| 4 | Recent fallow | 6378080 | 14.29 |
| 5 | Thick vegetation | 7220816 | 20.71 |
| 6 | Open ground | 1322720 | 3.02 |
| 7 | Water body | 5392 | 0.02 |

residential, institutional, commercial and industrial areas as well as public amenities and utilities along with government offices, religious/ cultural buildings, roads and dry rivers bed. The built up land increased drastically in recent years as Dehradun became the capital of newly formed Uttranchal state. This has resulted in migration of population from the nearby less developed hilly regions. Increase in built up area caused a rapid decrease in cropland, which is only 9.3% of the total area. The recent fallow land was 14.3%,

**Table 3.** Ward-wise area (%) under each land use/cover class

| Ward | Classes | | | | | | |
|---|---|---|---|---|---|---|---|
| No. | Cloud | Built up | Cropland | Recent fallow | Thick vegetation | Open ground | Water body |
| 1 | 0 | 25.86 | 0 | 44.83 | 18.97 | 10.34 | 0 |
| 2 | 0.01 | 80.21 | 3.93 | 6.31 | 9.30 | 0.24 | 0 |
| 3 | 0.01 | 97.48 | 1.42 | 0.54 | 0.27 | 0.28 | 0 |
| 4 | 0 | 99.23 | 0.68 | 0.09 | 0 | 0 | 0 |
| 5 | 0 | 83.58 | 3.99 | 4.23 | 7.44 | 0.77 | 0 |
| 6 | 0 | 69.62 | 7.88 | 6.48 | 14.78 | 1.23 | 0 |
| 7 | 0 | 40.29 | 7.71 | 10.15 | 38.65 | 3.20 | 0 |
| 8 | 0 | 53.42 | 8.14 | 9.39 | 28.64 | 0.42 | 0 |
| 9 | 0 | 69.38 | 7.84 | 7.62 | 12.61 | 2.53 | 0.01 |
| 10 | 0.01 | 60.91 | 8.21 | 9.80 | 14.64 | 6.41 | 0.03 |
| 11 | 0 | 41.47 | 7.36 | 11.64 | 32.32 | 7.21 | 0 |
| 12 | 0 | 72.64 | 6.69 | 9.86 | 10.13 | 0.68 | 0 |
| 13 | 0 | 6.97 | 25.29 | 43.81 | 22.19 | 1.75 | 0 |
| 14 | 0 | 68.41 | 8.78 | 9.89 | 12.22 | 0.70 | 0 |
| 15 | 0 | 67.19 | 5.85 | 7.15 | 17.91 | 1.91 | 0 |
| 16 | 0 | 45.76 | 11.45 | 19.87 | 15.14 | 7.77 | 0.02 |
| 17 | 0 | 87.85 | 5.45 | 1.47 | 3.97 | 1.26 | 0 |
| 18 | 0 | 91.84 | 2.37 | 2.25 | 1.49 | 2.00 | 0.05 |
| 19 | 0 | 92.53 | 2.78 | 2.02 | 1.53 | 0.32 | 0.83 |
| 20 | 0 | 88.76 | 2.47 | 1.91 | 6.85 | 0 | 0 |
| 21 | 0 | 88.58 | 3.57 | 3.87 | 3.58 | 0.40 | 0 |
| 22 | 0 | 96.99 | 1.61 | 0.74 | 0.66 | 0 | 0 |
| 23 | 0 | 86.85 | 4.28 | 2.67 | 6.20 | 0 | 0 |
| 24 | 0 | 97.62 | 1.00 | 0.90 | 0.48 | 0 | 0 |
| 25 | 0 | 49.88 | 6.72 | 12.08 | 27.91 | 3.41 | 0 |
| 26 | 0 | 81.33 | 5.31 | 6.60 | 6.32 | 0.36 | 0.08 |
| 27 | 0 | 48.84 | 7.26 | 11.73 | 30.08 | 2.09 | 0 |
| 28 | 0 | 75.37 | 6.36 | 7.63 | 9.50 | 1.15 | 0 |
| 29 | 0 | 42.14 | 6.69 | 13.97 | 36.51 | 0.69 | 0 |
| 30 | 0 | 21.38 | 1.38 | 35.86 | 35.17 | 6.21 | 0 |
| 31 | 0 | 81.43 | 7.00 | 4.49 | 4.99 | 1.96 | 0.13 |
| 32 | 0 | 35.89 | 12.25 | 6.98 | 40.28 | 4.60 | 0 |
| 33 | 0 | 56.61 | 9.63 | 3.74 | 28.35 | 1.66 | 0 |
| 34 | 0 | 70.66 | 10.33 | 3.48 | 12.63 | 2.90 | 0 |
| Total | 0 | 52.68 | 9.27 | 14.30 | 20.71 | 3.02 | 0.02 |

**Table 4.** Producer's and user's accuracy for various classes

| Class name | Reference totals | Classified totals | Number of correct pixels | Producer's accuracy (%) | User's accuracy (%) |
|---|---|---|---|---|---|
| Cloud | 0 | 0 | 0 | — | — |
| Builtup | 26 | 23 | 22 | 84.6 | 95.7 |
| Cropped land | 4 | 6 | 4 | 100.0 | 66.7 |
| Recent fallow land | 3 | 5 | 2 | 66.7 | 40.0 |
| Thick vegetation | 15 | 14 | 14 | 93.3 | 100.0 |
| Open ground | 2 | 2 | 2 | 100.0 | 100.0 |
| Water body | 0 | 0 | 0 | — | — |
| Totals | 50 | 50 | 44 | | |

which was more than the cropland, as the imagery was taken in the month of April, when the *rabi* crops were harvested and the *kharif* crops were yet to be sown.

The next class, which follows the built-up area in terms of area covered, is the thick vegetation (20.7%). The city of Dehradun is on the foothills of the Himalayas and is partially covered by the forest. The Forest Research Institute, which has vast areas under thick vegetation cover, is also a part of the city. Moreover, mangoes and litchi orchard are also widely found within the city, which is a common feature even in the household with open land. The open land comprising of 3% of the total area includes the open grounds, parks and stadiums. With the use of very high-resolution imagery, clouds could also be detected. However, the area covered by clouds is only 256 $m^2$. Water bodies forms only 0.02% of the total area, which comprises of ponds near Gurudwara of Saharanpur chowk.

Regarding the ward-wise analysis, most of the wards in central Dehradun and on the outer fringe of eastern part are 80-90% of densely built up area (Table 3). It indicates that the built up area is maximum in ward no. 4, and least in ward no. 13. Less built up areas in ward 13 is accompanied by more cropland and recent fallow. This ward is on the outer periphery of the city and hence, less developed than those which are in the heart of the city. On the other hand, ward 4 is in the Old Dalanwala area of the city, which has maximum built up area and less crop land area. Area under thick vegetation is maximum in ward 32 which is the near Forest Research Institute, and very less in ward 3, 4, 22 and 24.

**Table 5.** Kappa statistics for each category

| Class Name | Kappa statistic |
|---|---|
| Cloud | 0.0000 |
| Built up | 0.9094 |
| Cropped land | 0.6377 |
| Recent fallow land | 0.3617 |
| Thick vegetation | 1.0000 |
| Open ground | 1.0000 |

For calculating the overall accuracy, producer's accuracy and user's accuracy 50 random points were taken (Table 4). According to the error matrix an overall accuracy of 88% was obtained. The overall Kappa statistic was obtained as 0.82, and was variable for each land use class (Table 5).

## Conclusions

The study revealed the potential of multispectral high resolution IKONOS data for broad level mapping and monitoring in land use/ land cover over a period of time. Thus, this is the most reliable source of information if ground truth is done in a proper manner. Moreover, high spatial resolution sensor could be very informative for level II and III land use/cover classification. It may be concluded that high-resolution satellite imagery will be ideal, cost- and time-effective for producing base-maps of towns, villages, slum areas or unauthorized structures. Town planning departments should take initiative at their own level to expedite the production of base-maps.

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