

Enhanced capabilities of IRS P6 LISS IV sensor for urban mapping

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In this study, an attempt has been made to evaluate the information content available in IRS P6 LISS IV data for the identification of urban features and urban mapping. Level-III of the urban land use classification at the scale of 1 : 10,000 was successfully attempted for Dehradun city and its environs. A qualitative and quantitative evaluation of IRS P6 LISS IV data has also been done with PAN-sharpened LISS III data. The boundaries of polygon features, road intersections, contrast with the surroundings are more precise on LISS IV data in comparison to merged data. It is also found that 100% more linear features can be extracted with IRS P6 LISS IV data compared to PAN-sharpened LISS III product.

Keywords: Dehradun, IRS P6 satellite, LISS IV sensor, PAN data, urban mapping.

BY virtue of its multispatial and multispectral capabilities in one platform, IRS P6 has aroused the interest of the user community to seek newer applications. This satellite is providing remote sensing data services on an operational basis for integrated natural resources management in continuation with the services of IRS 1D with enhanced capabilities. The LISS IV sensor on-board this satellite, has the same spatial resolution of 5.8 m as that of IRS 1D PAN, but it has enhanced spectral resolution. LISS IV sensor consists of three spectral bands in the green, red and near infrared regions of the electromagnetic field. It can be tilted up to $\pm 26^\circ$ in the across-track direction, thereby providing a revisit period of 5 days and 70×70 km stereo pairs. This opens a new field of micro-level applications. Early results¹ of the studies done on Resourcesat data demonstrate various applications in all the fields with enhanced level of detailing. The study presents a variety of applications with IRS P6 data and suggests some new vistas of applications for infrastructure and urban-related studies. Pandey and Tiwari² have done forest mapping at compartment level using IRS P6 LISS IV data. It was found that LISS IV data facilitate better discrimination of different forest types and detailed micro-level information is possible using these data.

It is important for resource planners to evaluate the capabilities of any sensor to fully understand its potential and

the level of applications possible. There is a strong relationship between spatial and spectral resolution of the imagery and level of application. Technological advancements in the form of newly available imagery require undertaking an assessment of its capabilities, so that one can select appropriate imagery for appropriate level of application³. Forghani⁴ has carried out an assessment of KOMPSAT-1 vs SPOT-2/4 satellite imagery for maintenance of Geo-science Australia topographic databases. In this study an assessment of the sharpness, clarity and reliability of information with respect to mapping of urban features was carried out on both the imageries. It was also found that the visual interpretation is best suited for urban mapping. Gupta and Anil Kumar⁵ evaluated IRS LISS III, IRS LISS III+PAN merged and IKONOS MS+PAN merged products to assess the level of information available in each product for urban planning exercises. It was found that different datasets are suitable for different levels of exercise, i.e. LISS III, LISS III + PAN and IKONOS MS + PAN data were found to be suitable for broad land-use mapping at 1:50,000 scale for city-level mapping at 1:12,500 scale and for sub-city-level mapping at 1:2,000 scale respectively. Raju *et al.*⁶ carried out comparative analysis of information that can be derived from IRS 1C PAN data and SPOT PLA data for urban area mapping at 1:25,000 scale. The study reveals that twofold more transport network can be unambiguously mapped with IRS 1C PAN data compared to SPOT PLA data. Fard *et al.*⁷ evaluated the potential of SPOT-5 imagery for the revision of maps at 1:25,000 scale. Results of feature extraction showed that there was no difficulty in detecting and identifying area features such as towns, smaller villages and isolated buildings. All linear features such as roads, tracks, railways, etc. were extracted easily, except in some places where the contrast was relatively low. Finally, point features such as water/gas wells and single trees were impossible to be detected and identified on the image. Banzhaf Ellen and Netzband Maik⁸ used IRS 1C PAN data to evaluate the semi urbanization processes in peri-urban spaces using automatic classification technique. With this point of view, an attempt has been made in this study to evaluate the enhanced capabilities of the LISS IV sensor for urban feature identification and urban mapping. For this purpose, the LISS IV data have been assessed qualitatively and quantitatively and compared with PAN-sharpened LISS III merged product.

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Study area

Dehradun city and its environs have been selected as the study area ($78^{\circ}55'$ to $78^{\circ}5'E$ and $30^{\circ}12'$ to $30^{\circ}23'N$). It is the intermittent capital of Uttaranchal, besides being the district headquarters. It is the only municipal corporation of Uttaranchal. Its strategic location at the foothills of the Himalayas and serving as a gateway to the hills, has made it an important hill-station in India. Dehradun has emerged as the premier business as well as service centre within the hilly region of the state⁹. The functional character of the city is changing from an educational town to a service and commercial hub for the entire state.

Data and methodology

The LISS IV sensor of IRS P6 satellite has the same spatial resolution (5.8 m) as that of the IRS 1D PAN data and same spectral resolution as IRS 1D LISS III data of spatial resolution of 23.5 m. Data used in this study include IRS P6 LISS IV imagery (Path/Row 202/50 dated 11 April 2004), IRS P6 LISS III imagery (Path/Row 96/49 dated 5 May 2004) and IRS 1D PAN imagery (Path/Row 96/49 dated 10 February 2004). After georeferencing all datasets, the PAN-sharpened LISS III merged product was generated using Brovey transform technique. LISS IV data have

been analysed to assess the extent of urban feature extraction, level of mapping and the level of information. A detailed urban land-use mapping at 1:10,000 scale (level-III of the urban land-use classification)¹⁰ was attempted. Subjective visual interpretation supported by background knowledge for the extraction of urban features such as high-density residential developments, sparse developments in fringe areas, roads, drainage, industrial structures, water bodies, etc. was also taken up for visual analysis to observe the level of sharpness, clarity and reliability of information in LISS IV data compared with PAN-sharpened LISS III product. The second part of the methodology focuses on quantitative investigation of LISS IV imagery with the PAN-sharpened LISS III product. The road network and drainage network of the study area were extracted from both the images in different categories and the extent of mapping was thus compared for each category. Using ground information, all the layers generated were refined and the refined layers were then used for analysis.

Results and discussion

Urban land-use mapping with IRS P6 LISS IV

Dehradun and its surroundings were mapped using the IRS-P6 LISS IV data. An urban land use map was prepared

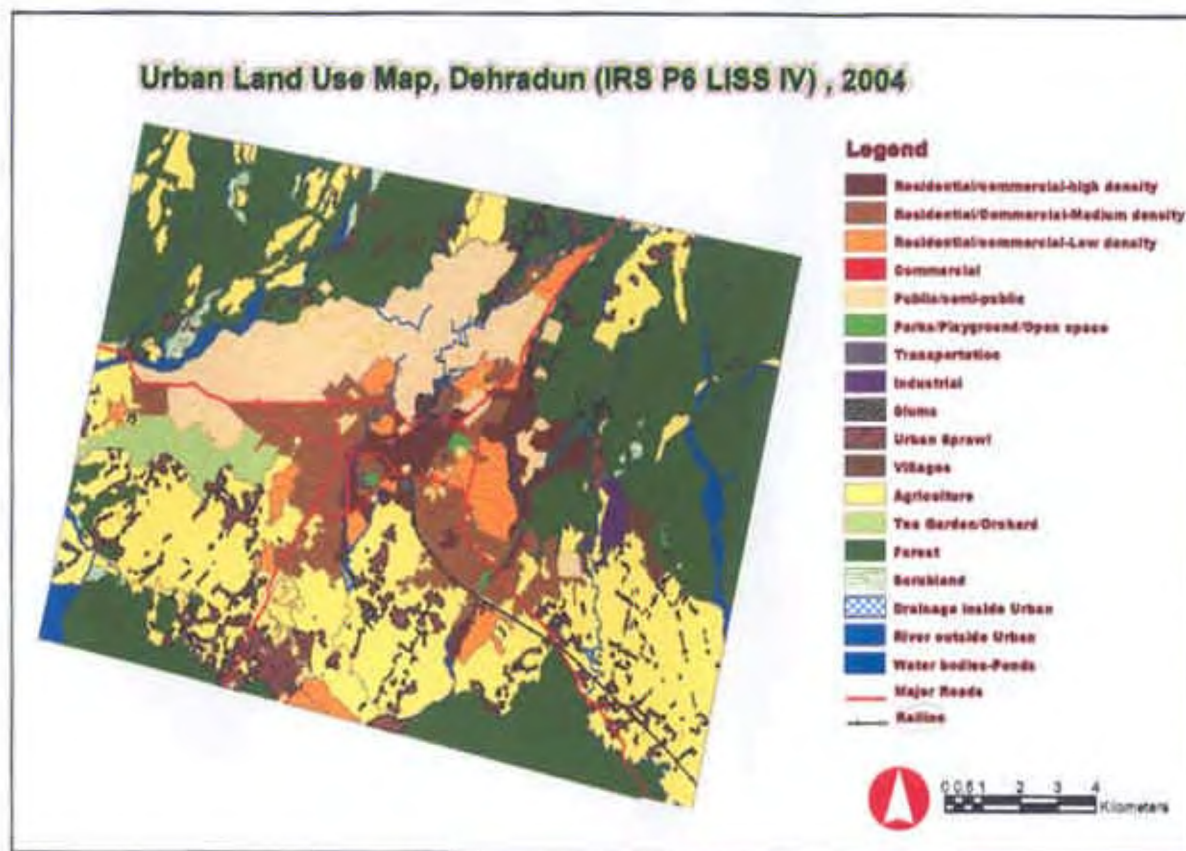


Figure 1. Urban land-use map (level-III classification) prepared from IRS P6 LISS IV imagery for Dehradun, India.

and mapped at 1 : 10,000 scale (Figure 1). Level-III of the urban land use was successfully attempted using the data. It was found that it has high information content, which shows the enhanced capabilities of the sensor. Earlier, with this resolution, only level-II mapping of urban land use was possible, but here it provides more information on urban features.

A total of 18 classes were mapped, among which ten are urban land-use classes. An analysis of all the mapped classes shows that the major land uses in the study area are forest, built-up area and agriculture respectively (Table 1). Almost 35% of the study area comes under the category of forest land use, which is due to large amount of reserved forest area around the city. It also creates the physical boundaries of the city. With the influx of population over the last few years, the city is growing rapidly along the transport corridors and beyond forest boundaries. The next major land-use category is the built-up area, which consists of Dehradun urban area and villages around the city. In the valley plain of the study area, there is a good amount of agricultural activity, which consists almost 28% of land area. All categories of water bodies form less than 4% of the total study area. Most of the water bodies in the study area are in the form of rivers, majority being seasonal rivers.

In urban land-use classes, almost 50% of the urban area comes under residential/commercial activity (Table 2). The city has a spread development, as almost 50% of residential land use has medium density. The high-density residential area in the city forms the central business district as well. The next major urban land-use category is institutional, showing the educational character of the city.

The city has a good amount of green space as part of the low-density residential area and public/semi-public institutional buildings. A significant finding is that more than 16% of built-up area comes under urban sprawl category, which shows rapid urbanization around Dehradun city. Dehradun is one of the cities growing fast and emerging as the major service, commercial and institutional city in its region.

Table 1. Summary of various land-use classes mapped using IRS P6 LISS IV data

Land-use category	Area (ha)	Area (%)
Urban area	7997.88	31.35
Village	109.07	0.43
Agriculture	7039.91	27.61
Forest	8855.28	34.73
Scrubland	205.36	0.81
Tea garden/orchard	488.55	1.92
Drainage inside urban	26.99	0.11
River outside urban	772.77	3.03
Water bodies – ponds	4.43	0.02
Total	25500.24	100.00

Qualitative assessment of IRS P6 LISS IV data

The LISS IV data of Dehradun region have been compared with PAN-sharpened LISS III data of the same area. Urban features under various urban land use categories were selected in both the datasets for visual comparison.

Logically, both the datasets, i.e. LISS IV and PAN-sharpened LISS III image have the same spatial resolution. Thus equal amount of features should be visible on both the images. However, the major difference between both the datasets lies in their configuration. LISS IV data have unique pixel of 5.8 m resolution, whereas in PAN-sharpened LISS III product, spectral information comes from the breakdown of 23.5 m spatial resolution pixel into four pixels. Due to this reason, there is more contrast among features in LISS IV data compared to PAN-sharpened LISS III product. Hence, there is more clarity of features in LISS IV data compared to the merged data.

In residential areas, low density and medium density areas were selected and analysed visually (Figure 2 A, a; B, b). The precise boundaries of individual buildings can be identified and delineated in low and medium density residential areas with LISS IV data. In case of merged data, the boundaries of various polygons are not so precise and somewhat hazy at most places. In high-density areas, both datasets have their own limitations and it is not possible to identify individual buildings.

Boundaries of buildings in the industrial area (Figure 3 C, c) are also crisper and more precise on LISS IV data. Delineation of individual buildings is more accurate with LISS IV data compared to merged data. The newly constructed inter-state bus terminal (Figure 3 D, d) has also been picked up for visual comparison. It shows that LISS IV data provide clear boundaries of the various components of the terminal. In the case of merged data, it is difficult even to identify the campus and determine its use.

Athlete track and playgrounds (Figure 3 A, a; B, b) were also compared visually. The enhanced capabilities of LISS IV are quite clear, as delineation of the track and other details of playgrounds are more clear on LISS IV. The

Table 2. Summary of detailed urban land-use classes mapped from IRS P6 LISS IV data

Urban land use category	Area (ha)	Area (%)
Residential/commercial – high density	910.45	11.38
Residential/commercial – medium density	1882.06	23.53
Residential/commercial – low density	982.26	12.28
Commercial	3.98	0.05
Public/semi-public	2685.55	33.57
Industrial	112.34	1.40
Parks/playground/open space	64.73	0.81
Transportation	28.79	0.36
Slums	20.94	0.26
Urban sprawl	1306.78	16.34
	7997.89	100

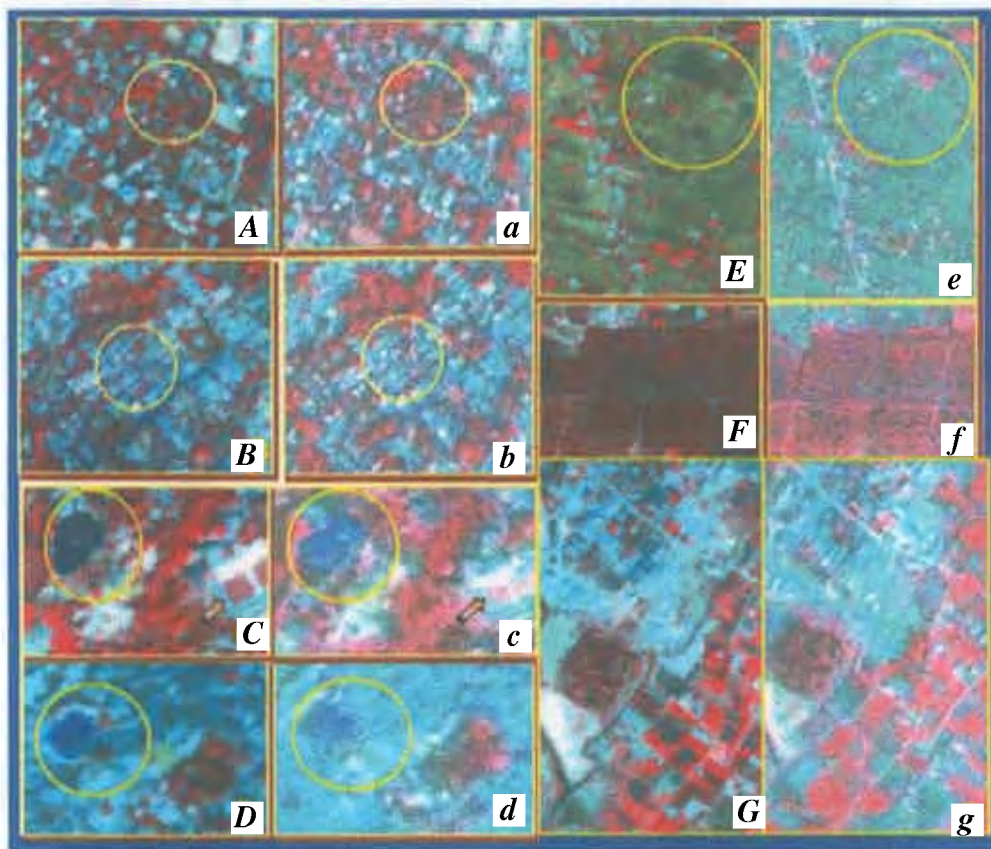


Figure 2. Images of various urban features for visual comparison. (Capital letters presents IRS P6 LISS IV images and small letters present PAN-sharpened LISS III images.) *A, a*, Low density residential development. Boundaries of individual residential buildings are more precise on LISS IV image. *B, b*, Medium density residential development. Here also individual buildings are crisper on LISS IV image comparatively. *C, c*, Edges of natural water body can be clearly delineated from LISS IV image, but in PAN-sharpened LISS III image, the edges are hazy. *D, d*, Clarity in delineation of artificial water body from LISS IV image is apparent. *E, e*, Edges of agricultural fields can be easily delineated from LISS IV data comparatively. *F, f*, It is apparent from imageries that LISS IV data give precise boundaries of tea garden patches compared with PAN-sharpened LISS III. *G, g*, Whole section of drainage can be delineated accurately from LISS IV data, but only partial drainage can be delineated from PAN-sharpened LISS III.

delineation of water bodies is also an important aspect of urban land-use mapping. The extent of water bodies, both natural and man-made (Figure 2 *C, c*; *D, d*), are much more precise when mapped with LISS IV data. However, on the merged dataset, it is not visible. Even the boundaries of agricultural fields and tea gardens are found to be more precise when mapped with LISS IV data (Figure 2 *E, e*; *F, f*). It shows the enhanced capabilities of this sensor in terms of cadastral mapping of urban areas.

A road junction, Saharanpur chowk of Dehradun city is shown (Figure 3 *E, e*). On the merged data, the junction is not clear. It has been delineated with ground knowledge. But curvature of the junction and roads joining each other are clear and prominent in LISS IV image. Drainage network of the city is also selected for visual comparison. On the images, it is clearly visible that with LISS IV data, the whole section of drainage could be mapped but in case of merged data, only partial drainage could be delineated (Figure 2 *G, g*).

The above discussion clearly shows the superiority of LISS IV data for identification of urban features over merged data. It has been found useful in delineating individual buildings and their land use. Mapping of urban land use at city level can be done with either of the datasets as in case of city-level land use; a group of buildings rather than an individual building determines the land use of a particular area.

Quantitative assessment of IRS P6 LISS IV data

From visual comparison of both datasets, the superiority of LISS IV over PAN-sharpened LISS III imagery is quite apparent. There is a need to understand to what extent, in quantitative terms, LISS IV imagery is better than PAN-sharpened LISS III product. With this point of view, road and drainage networks in the study area were extracted from both the images and length of these features in each category was compared.

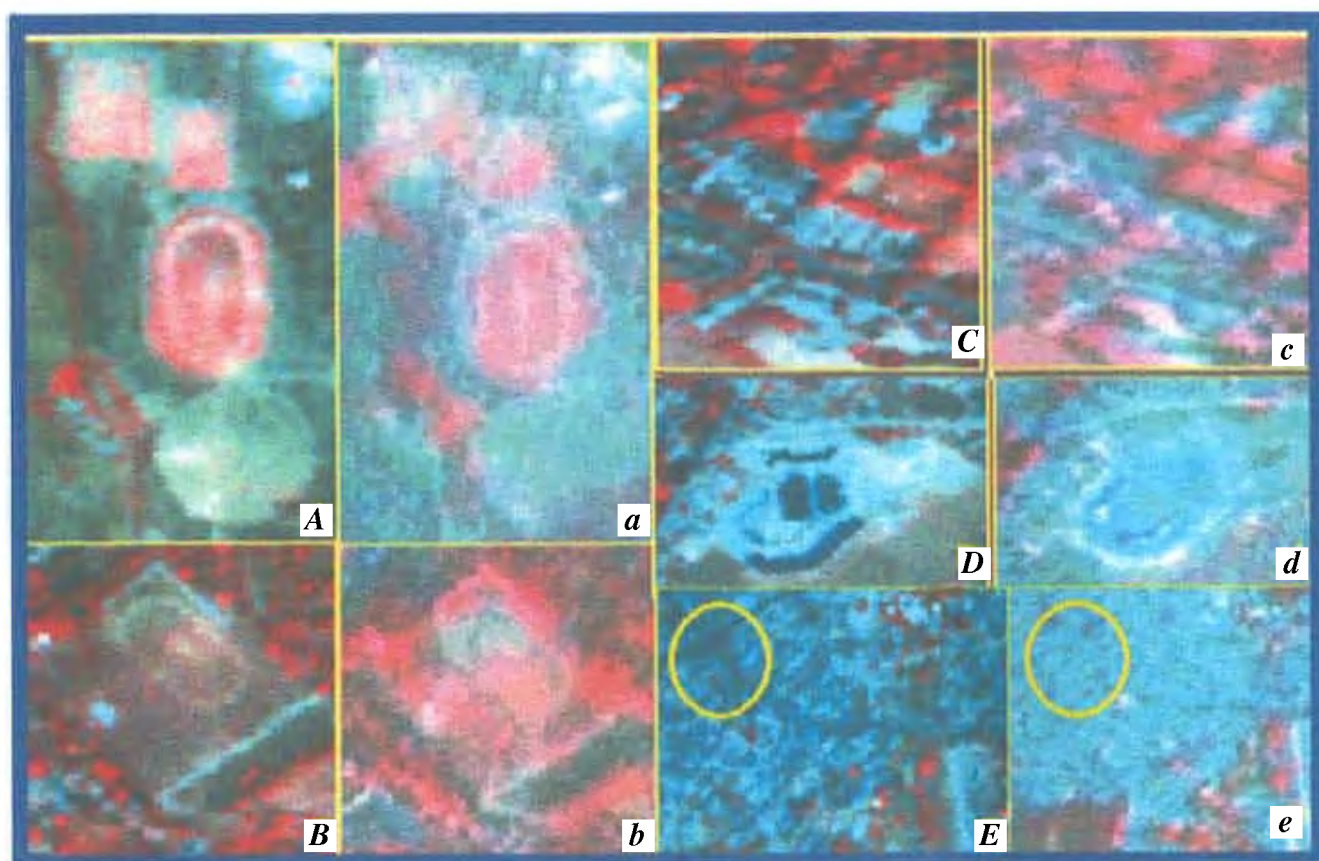


Figure 3. Images of various urban features for visual comparison. (Capital letters presents IRS P6 LISS IV images and small letters present PAN-sharpened LISS III images.) *A, a*, The playgrounds have sharper boundaries when imaged with LISS IV data. *B, b*, Athletic track has more clarity of delineation from LISS IV data comparatively. *C, c*, Individual buildings in the industrial complex are clearer in LISS IV image but boundaries are hazy in PAN-sharpened LISS III image. *D, d*, Newly constructed inter-state bus terminal of Dehradun city clearly visible in LISS IV image. *E, e*, Curvature and junction of roads is sharp on LISS IV image, while in case of PAN-sharpened LISS III it can be delineated only with ground knowledge.

Table 3. Length of roads in various categories extracted from IRS P6 LISS IV data and PAN-sharpened LISS III image

Category	Road extracted from LISS IV (length in km)	Road extracted from PAN-sharpened LISS III (length in km)
Major roads	65.98	51.14
Secondary roads	101.57	53.55
Tertiary/local roads	84.85	42.04
Village roads	45.17	24.92

The road network of the city was mapped in three broad categories of urban roads and one category of rural roads. The categories of urban roads are: major roads, secondary roads and tertiary roads (Figure 4). It is clear that the extent of roads mapped from LISS IV data is much more compared to merged data. Statistics of the length of the roads mapped is given in Table 3. The comparison shows a significant difference in the extent of the roads mapped from both the

datasets. Figure 5 also confirms the data given in Table 3. The length of major roads was 30% more from LISS IV data compared to merged data. Although in case of major roads the difference is comparatively less, it also demonstrates better clarity of linear features in case of LISS IV data compared with PAN-sharpened LISS III. In case of secondary roads, tertiary roads and village roads, the difference in the extent of mapping from both datasets is much more significant. The length of secondary roads, tertiary roads and village roads is extractable up to 89.68, 101.83 and 81.28% respectively, from LISS IV data, i.e. almost 100% more information on the road network could be extracted from LISS IV data compared to merged product.

In the same manner, the drainage network of the city was also extracted from both datasets and the same analysis was attempted. The overlay map of the drainage network from both datasets is presented in Figure 5. Here one can see that outside the urban area, where drainage is more of a polygon feature, there is less difference. But inside the urban area, where drainage becomes the linear feature

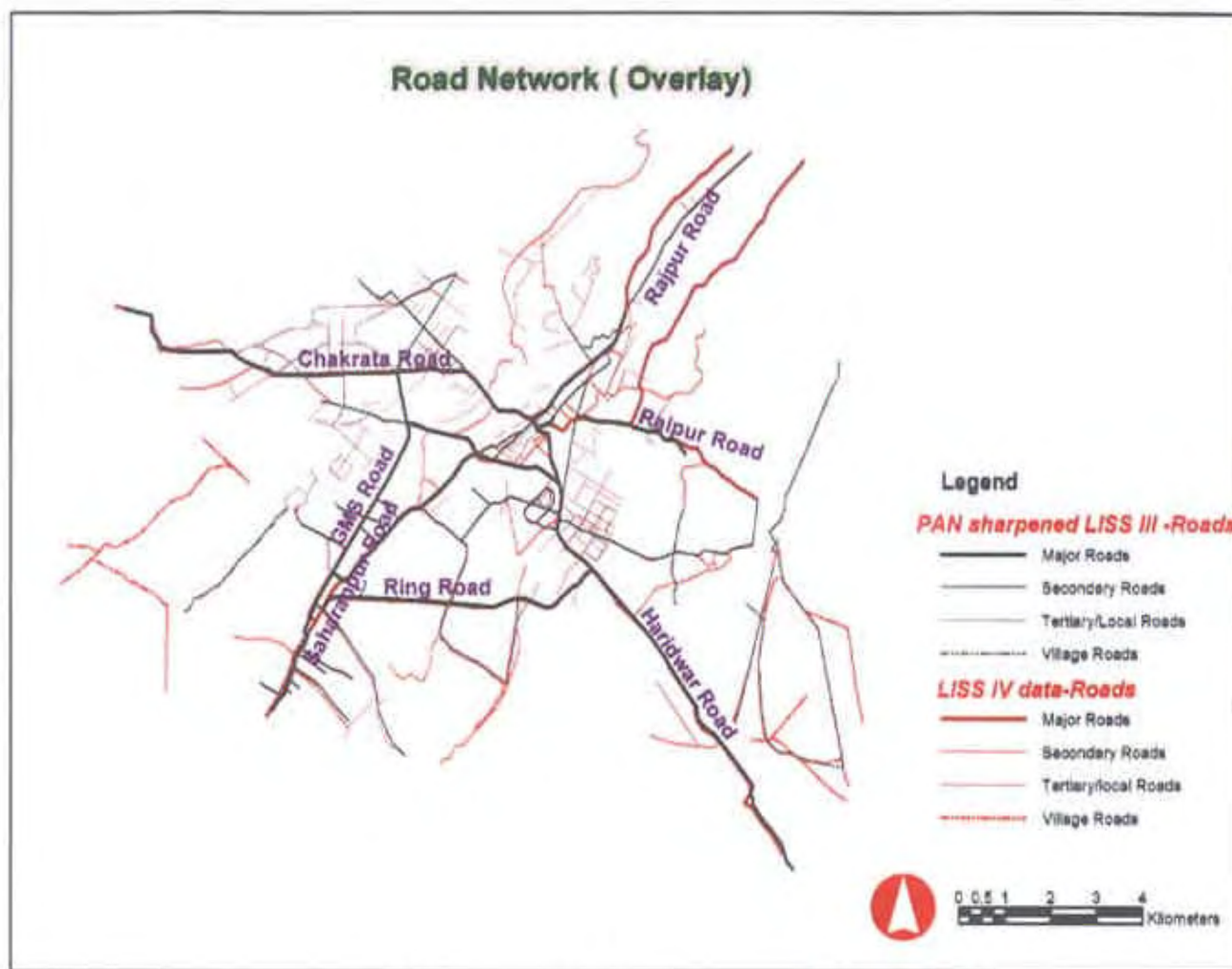


Figure 4. Overlay map of roads extracted under different categories from LISS IV and PAN-sharpened LISS III images.

Table 4. Length of drainage extracted from IRS P6 LISS IV data and PAN-sharpened LISS III image

Category	Drainage extracted from LISS IV data (length in km)	Drainage extracted from PAN-sharpened LISS III (length in km)
Drainage inside urban	35.96	22.03
River outside urban	32.83	28.78

with respect to spatial resolution of the both datasets, there is a significant difference in the extent of drainage mapped from both datasets. Statistics of the analysis is presented in Table 4. It shows that in case of drainage outside urban area, around 4 km more in length, i.e. 14% more information could be extracted from LISS IV data compared to PAN-sharpened LISS III data. In case of drainage inside the urban area around 14 km, i.e. 63.2%

more information could be extracted from LISS IV compared with PAN-sharpened LISS III product.

The quantitative comparison of both the datasets again emphasized the enhanced capabilities of LISS IV data over PAN-sharpened LISS III product in terms of mapping of linear features. It also demonstrates comparatively high information content, i.e. 100% more information is available in LISS IV data in comparison with PAN-sharpened LISS III image.

Conclusion

The study demonstrates that although there are several techniques available for data fusion, the unique pixel having unique spectral value gives better results for identification of urban features. The LISS IV imagery gives crisper boundaries of polygon features such as residential buildings and clear details of industrial complexes, which makes the delineation of individual buildings more accurate. How-

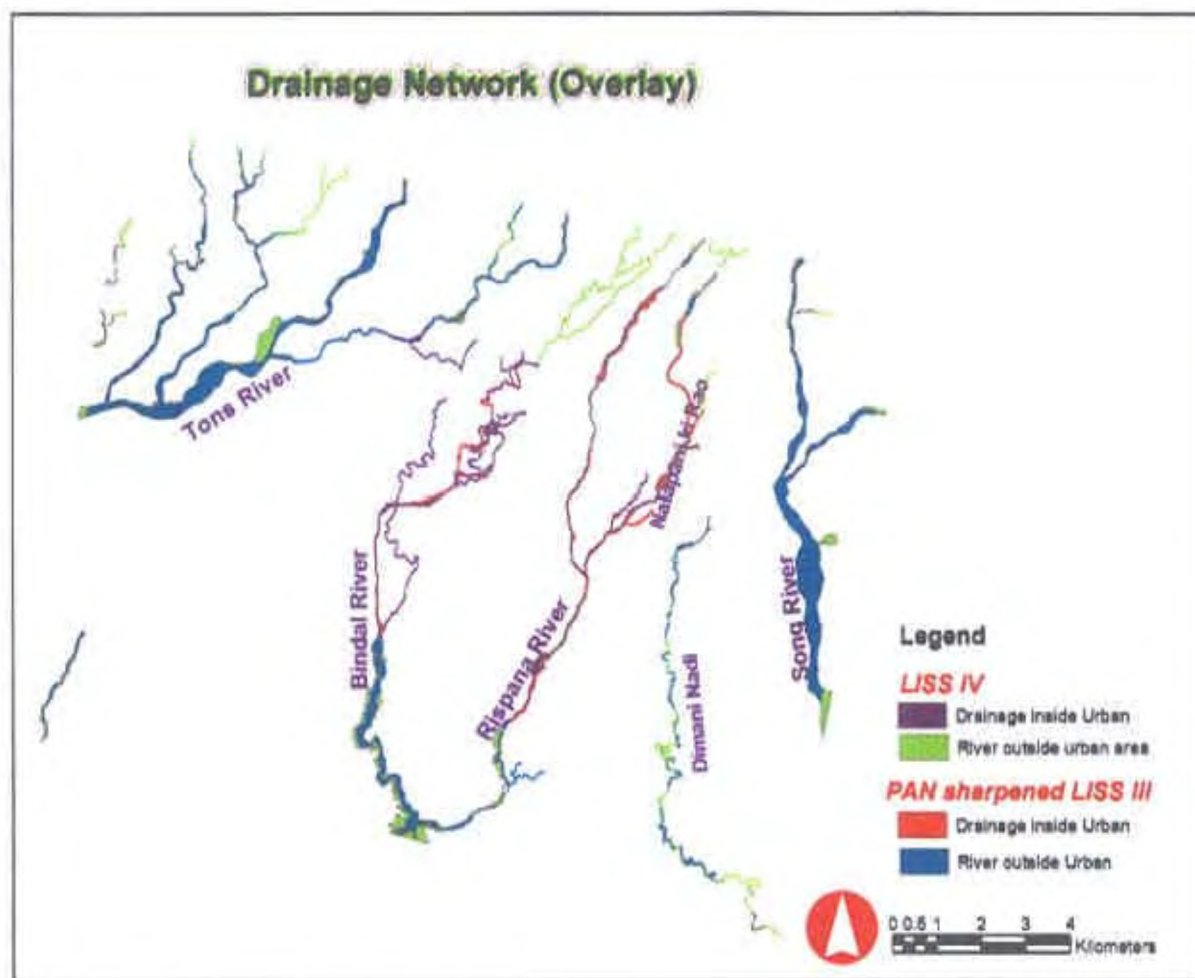


Figure 5. Overlay map of drainage extracted under different categories from LISS IV and PAN-sharpened LISS III images.

ever, while mapping urban land uses, the statistics may not differ much from both the datasets as a group of buildings decides the land use of a particular area. LISS IV data provide more accuracy in the delineation of individual urban features.

LISS IV imagery has been found extremely suitable for identification and delineation of linear features such as road network, drainage, etc. inside a city area. About 100% more linear features could be identified with LISS IV data compared to PAN-sharpened LISS III image. Besides, in case of LISS IV data, one requires to use only one dataset, which implies comparatively less disk space and processing requirements.

The study also shows that with LISS IV data, the level of classification improves as well. One can go up to level-III of urban land-use classification using visual interpretation technique, even in cities like Dehradun which is medium in size and population, and also has an undulating terrain. It also facilitates various applications at city level, such as urban land-use change analysis, urban sprawl detec-

tion, cadastral mapping, etc. Based on limited analysis, it is concluded that LISS IV data provide better accuracy in identification of urban features. However, in the case of broad-level land-use classification, both datasets provide the same results.

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