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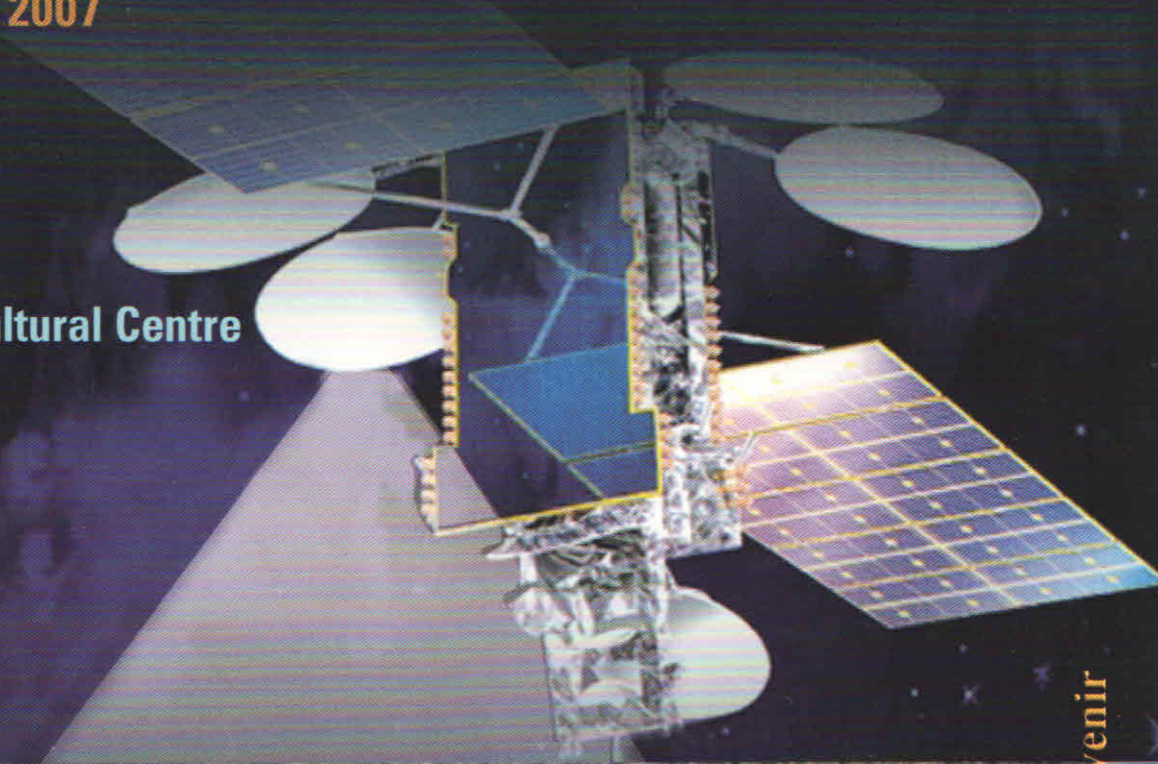

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# Quantification of Confusion in LISS-III & LISS-IV Data for Urban Land-cover Classification

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Mixed pixel and mixed class confusions are common problems in remote sensing image classification, which restrict us to achieve high level of accuracy in classification. Accuracy level of classification varies sensor to sensor with the change in spatial, spectral and radiometric resolution. Accuracy also varies with the change in classification algorithm, change in study area and change in desired information classes for a specific sensor. So, it is very important to evaluate the performance of a sensor and to compare the performance with other sensors in a wide range of variety. These studies enable us to choose appropriate sensor for a specific application depending upon the type of study, nature of study area, availability of fund and obviously above of all the requirement of accuracy. In this study it has been tried to quantify the overall confusion of LISS-III data and LISS-IV data of IRS Resourcesat-1 for the ISODATA unsupervised land-cover classification of urban area. The result shows 45-54% overall confusion in LISS-III data and 15-20% overall confusion in LISS-IV data for urban land-cover classification. Overall confusion in urban land-cover classification reduces by 30% in LISS-IV data comparing LISS-III.

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# Assessment of IRS-P6 LISS-III and LISS-IV data towards urban land-cover classification

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**Abstract:** Mixed pixel and mixed class confusions are common problems in remote sensing image classification, which restrict us to achieve high level of accuracy in classification. Accuracy level of classification varies sensor to sensor with the change in spatial, spectral and radiometric resolution. Accuracy also varies with the change in classification algorithm, change in study area and change in desired information classes for a specific sensor. So, it is very important to evaluate the performance of a sensor and to compare the performance with other sensors in a wide range of variety. These studies enable us to choose appropriate sensor for a specific application depending upon the type of study, nature of study area, availability of fund and obviously above of all the requirement of accuracy. In this study it has been tried to quantify the overall confusion of LISS-III data and LISS-IV data of IRS-P6 (Resourcesat-1) for the ISODATA unsupervised land-cover classification of urban area. The result shows 45-54% overall confusion in LISS-III data and 15-20% overall confusion in LISS-IV data for urban land-cover classification. Overall confusion in urban land-cover classification reduces by 30% in LISS-IV data comparing LISS-III.

**Keywords:** LISS-III, LISS-IV, Spectral/spatial confusion, Urban land-cover classification, Mixed class, Mixed pixel.

## 1. Introduction

For any given material, the amount of solar radiation that reflects, absorbs, or transmits by the material is important property of the matter which makes it possible to identify different substances or classes and separate them from others. Sensors are devices used for making observations. The major characteristics of an imaging Remote-Sensing instrument operating in the visible and infrared spectral bands are described in terms of its spatial, temporal, spectral and radiometric resolutions.

Spatial resolution is a key element of a sensor performance in remote sensing (Bhuyan *et al*., 2007). The detail discernible in an image is dependent on the spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors depends primarily on their Instantaneous Field of View (IFOV). The IFOV is the angular cone of visibility of the sensor and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time. The IFOV may also be defined as the area on the ground, which is viewed by a single instrument from a given altitude at any given instant of time (Jensen, 2004).

The information within an IFOV, is presented by a picture element in the image plane usually referred to as pixel. For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell. If the feature is smaller than this, it may not be detectable as the average brightness of all features in that resolution cell will be recorded. However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel detection.

Spatial resolution can also be thought of in terms of the ground surface distance (GSD) capability of the sensor. GSD for an image is comparable to the minimum mapping unit for a map. A rough but practically useful rule to use when selecting imagery to discern attributes of given size is that the sensor must be able to detect objects one-half the size of the object to be identified (i.e., if we want to be able to find something 20 meters in size, we must have imagery that collects data in pixels 10 meters square).

The use of satellite imagery to map urban landscapes has met with varying degrees of success (Quattrochi, 1983; Toll, 1984; Duggin *et al*., 1986; Haack *et al*., 1987; Sadowski *et al*., 1987; Bhuyan *et al*., 2007). Buchan and Hubbard (1986) reported that even the 20 m multispectral resolution of the SPOT image is insufficient for mapping the heterogeneity of some inner city areas. In low spatial resolution image, larger ground area makes a mixed pixel instead of homogeneous pixel. A mixed pixel is a pixel whose digital number (DN) represents the average energy reflected or emitted by several types of surface present within the area that it represents on the ground; sometimes called a mixel. This problem increases in the urban areas as because within a very small transect the heterogeneity of land cover is very high comparing with rural or other areas.

Spectral resolution refers to the number and dimension of specific wavelength intervals in the electro-magnetic spectrum to which a remote sensing instrument is sensitive. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges. High spectral resolution is achieved by narrow band widths which, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad band widths. Spectral resolution not only relates with the dimension of the bandwidth but also the number of bands. Individual bands and their widths will determine the degree to which individual targets can be discriminated on a multispectral image. The use of multispectral imagery can lead to a higher degree of discriminating power than any single band on its own. Lower spectral resolution does not create a mixed pixel, instead it creates mixed class, i.e., pixels representing different objects will belong to a single class. Class is a group of pixels relating to a narrow or broad category of objects over the earth surface.

The radiometric resolution is defined as the sensitivity of a remote sensing detector to differences in signal strength as it records the radiation flux reflected or emitted from the terrain. It defines the number of just discriminable signal levels; consequently, it can have a significant impact on our ability to measure the properties of scene objects. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor, the more sensitive it is to detect small differences in reflected or emitted energy. Lower radiometric resolution is also responsible for mixed class instead of mixed pixel.

The availability of data from sensors with different resolutions necessitates a comparative evaluation (Williams *et al.*, 1984; Price, 1984) of their performance for classification (Irons *et al.*, 1985; Johnson and Hwarth, 1987, Sahai *et al.*, 1988; Dadhwal and Parihar, 1990; Navalgund *et al.*, 1996; Singh *et al.*, 2002; Bhuyan *et al.*, 2007). Some early evaluation studies of sensors onboard Resourcesat-1 have already been carried out and reported (Oza and Bhanderi, 2004; Seshasai *et al.*, 2004; Bhuyan *et al.*, 2007).

This type of evaluations is required to be focused on specific application. Because, the performance of a sensor to discriminate crop classes may not relate the performance to discriminate urban features. In this study it has been tried to quantify the confusion of classification on IRS-P6 LISS-III and LISS-IV data for a given urban area of same time. Temporal variation may also tend to varying level of confusion, which we can overcome by taking imageries of same date and time or at least similar atmospheric condition and applying necessary atmospheric corrections on the imageries.

A common but complex approach of comparing the performance of multiple sensors is to match the radiometric resolution of the sensors by stretching the histogram in to a common radiometric range, matching the spectral resolution by subsetting spectral band(s) (and/or applying arithmetic operations on DN values) so that the number of bands and their DN range of a sensor matches with other, matching the spatial resolution by resampling the higher resolution image so that it's pixel size matches with the lower resolution image and then performing analysis. To check the performance of one resolution (e.g. spatial resolution), other two resolutions of the comparing sensors are matched. However, this approach often restricts the full utilization of the data in terms of spatial, spectral and radiometry. Moreover, we get multiple quantification of the performance. No doubt, this approach has a very high scientific value, but it goes beyond the ability to quantify the overall performance or confusion in classification of a sensor for common analysts.

This paper is aimed to empirically devised study to quantify the overall performance of IRS-P6 LISS-III and LISS-IV data for urban land-cover classification.

## 2. Study area

This study is not to analyse a specific area, rather the aim is to analyse the level of acceptability of a sensor to classify urban landscape. Therefore, any urban area could be considered.

However, Victoria Memorial and some surrounding area (88°20'40.82"E to 88°21'13.85"E and 22°32'22.78"N to 22°32'50.18"N, 0.508 km²) of Kolkata, India has been considered for the said analysis. This area of Kolkata has medium dense built-up with good tree cover, grassland and clear water. The study was carried out on a small area because extensive ground check was required to achieve very high statistical accuracy.

Finally, it was necessary to evaluate the obtained result on a large urban area before drawing any conclusion. And, to satisfy this necessity, the same analysis was then performed on Kolkata city, under the jurisdiction of the Kolkata Municipal Corporation (KMC), has an area of 185 km² with 141 wards.

## 3. Data and methodology

Uncorrected Linear Imaging Self-scanning Sensor (LISS) - III and LISS-IV (multispectral) data of IRS-P6 (Resourcesat-1) of October 2005 have been used to quantify the confusion in urban land-cover classification.

The LISS-III of Resourcesat-1 is a multi-spectral camera operating in four spectral bands, three in the visible and near infrared (VNIR) and one in the shortwave infrared (SWIR) region with a spatial resolution of 23.5 m at nadir. The LISS-IV camera is a multi-spectral high resolution camera, captures image in three VNIR spectral bands with a spatial resolution of 5.8 m at nadir. The spectral resolutions of the sensors are as shown in Table 1.

Table 1: Spectral resolutions of LISS-III and LISS-IV

| Band No. | Band width | Sensor(s) |
|---|---|---|
| 2 (Green) | 0.52-0.59 | LISS-III & LISS-IV |
| 3 (Red) | 0.62-0.68 | LISS-III & LISS-IV |
| 4 (NIR) | 0.77-0.86 | LISS-III & LISS-IV |
| 5 (SWIR) | 1.55-1.70 | LISS-III only |

The LISS-III data from the VNIR bands are digitized to 7 bits and the data from SWIR band are digitized to 10 bits. While, all LISS-IV data bands are digitized in 10 bits.

It is worth mentioning that the LISS-III sensor of IRS-P6 is different than the earlier version of this sensor used in IRS-1C/1D. The new feature in LISS-III camera is the SWIR band, which provides data with a spatial resolution of 23.5 m unlike in IRS-1C/1D, where the spatial resolution is 70.5 m.

The LISS-IV data was geometrically rectified with 10 small landscape features located in the image data and evenly distributed. Sub-pixel registration accuracy was achieved. In the next step, LISS-III data was registered with the LISS-IV data using image-to-image registration method. A vector file of the study area (Victoria Memorial and surrounding) was used to clip both of the images. No alteration of spatial, spectral or radiometric resolution was performed on the imagery.

Digital classification was conducted using the non-hierarchical ISODATA (Iterative Self Organising Data Analysis Techniques) clustering algorithm on the above mentioned data with 99.99% convergence. With the ISODATA unsupervised approach, pixels were grouped into a set of 100 clusters (spectral classes), which were later identified via extensive ground checks and comparing PAN fused QuickBird image. Four basic urban land-covers (water, trees/bushes, grassland and built-up/bare/other impervious surface) have been tried to identify.

In the process of class identification two types of confusion have been faced:

i. pixel is not homogeneous, and
ii. spectral class is not homogeneous.

In both of the cases, if the confusion is more than 20%, the pixels were grouped into a class named 'Confusion'. If at least 80% of pixel area represents a specific information class then pixels were assigned to the associated information class. Though this approach is actually doing overestimation, but for multiple classes there is a possibility of normalising each other in terms of area. However this approach is not appropriate for high precision mapping requirements.

Homogeneity of a spectral class may be increased by introducing more number of clusters in unsupervised classification. But as we increase the study area, more heterogeneity introduces resulting more spectral confusion. Moreover if we go for sub-class classification the spectral confusion also increases. Keeping these factors in mind, for four/five coarser information classes and for a small study area, 100 spectral classes were considered.

After identification and aggregation of the spectral classes, two classification results (one for LISS-III and another for LISS-IV) were obtained (Figure 1), which were then used to quantify and compare the confusion of associated sensors for urban land-cover classification. Post classification accuracy assessment was not necessary as because during the class identification every spectral class was compared with extensive ground checks.

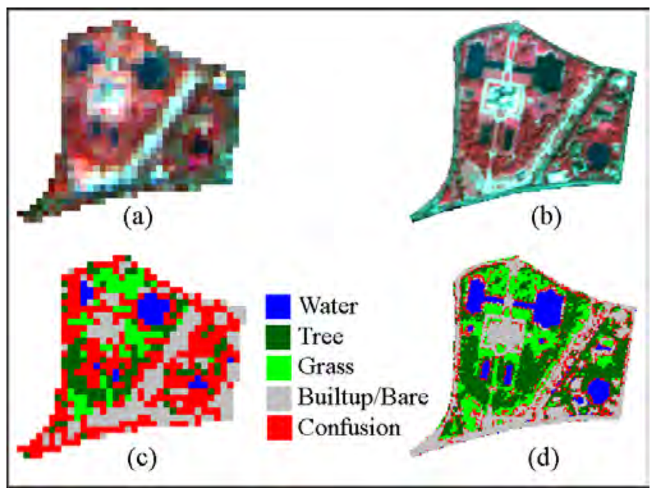


Figure 1: (a) LISS-III infrared colour composite
(b) LISS-IV infrared colour composite
(c) LISS-III classified
(d) LISS-IV classified

After getting the result, it was necessary to evaluate the result on a large and diverse urban area with more number of information classes. Therefore, the same analysis was then performed for Kolkata Municipal Corporation area (185 km$^2$), both for LISS-III and LISS-IV. This time 255 spectral classes were created which were then assigned to nine information classes (Trees, Scattered trees, Built-up, Bare ground, Grassland, Stressed grass, Agricultural land, Water/Wetland and Others) with another class for 'confusion'. However, this time it was not possible to compare with extensive ground checks to identify each spectral class. Cluster identification was achieved by on-site visits to 100 locations in the field, by comparing the previous studies, by personal experience and by comparing with PAN fused Quickbird image. This time post classification accuracy assessment was performed and very high (92-97%) classification accuracy was observed, because most of the confusions were accumulated in 'Confusion' class.

## 4. Result and discussion

The results of classification (for Victoria Memorial area) are summarised in Table 2. The result shows a quantum improvement in accuracy of LISS-IV data over LISS-III. In case of LISS-III, 55% of study area could be identified without major confusion and 45% of study area was confused. Whereas in LISS-IV, 85% area could be identified and only 15% area was in confusion.

Table 2: Result of classification

| | *LISS-III* | *LISS-IV* |
|---|---|---|
| Water* | 0.02405696 | 0.04829998 |
| Tree* | 0.07144188 | 0.1362749 |
| Grass* | 0.05467491 | 0.09392496 |
| Built-up/Bare* | 0.1312198 | 0.1560149 |
| Confusion* | 0.2274476 | 0.0736979 |
| Total* | 0.50884115 | 0.50821264 |
| Accuracy* | 0.28139355 | 0.43451474 |
| % accuracy | 55.30086354 | 85.4986094 |
| % confusion | 44.69913646 | 14.5013906 |

* Area in sq.km.

However, this result may vary due to several reasons, which are necessary to discuss. Performance of sensor is not constant for all type of study area and all type of classification algorithm. Mixed pixel confusion will dramatically increase with the increase of heterogeneity within a small transects. Mixed class confusion will also increase with the heterogeneity of the study area, especially when the study area is very large. With the increase in number of desired narrow information classes will also increase the spectral confusion.

As a result, the analysis on Kolkata Municipal Corporation area shows 20.21% confusion in LISS-IV data and 53.53% confusion in LISS-III data.

However, some other study shows that spectral confusion for classification can be minimized by subdividing the study area into several pieces, based on the nature of the area, especially if the study area is heterogeneous in nature (Iverson and Cook, 2000). The resulting subsets can then be used for classification separately with higher number of spectral classes, and finally, merging these subparts into a single one.

## 5. Conclusion

From the preceding analysis the following conclusions can be drawn:

Overall confusion decreases by 2/3 in LISS-IV data in comparison with LISS-III data for classifying urban land-cover.

For urban land-cover classification, the overall confusion of LISS-III data is 45-54%.

For land-cover classification, the overall confusion in LISS-IV data is 15-20%.

Overall confusion decreases by 30-34% in LISS-IV data comparing LISS-III data for classifying urban land-cover.

Overall confusion is not constant for a given sensor. Depending upon the accuracy requirement and the nature of the study area we should choose appropriate sensor.

Finally, it is worth mentioning that the reported accuracy or confusion is not constrained by rigid theoretical devices; neither does it impose theoretical restraints on the modelling of sensor performances. Since this is an empirically devised approach, it can be tested and extended to further urban areas as well.

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