

URBAN MONITORING USING SPOT IMAGERY - A CASE STUDY

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ABSTRACT:

The SPOT imagery of Madras area has been analysed using VAX 11/780 computer to demonstrate the feasibility of identifying the areas of urban expansion for monitoring and planning. The informations extracted from this imagery are compared with those obtained from Landsat TM imagery. The various bands of SPOT and TM data are independently integrated and classified into ten urban categories. To evaluate the quality of products obtained with the data simple accuracy measures such as user accuracy and producer accuracy were calculated with the help of field checks. This paper reports on the appropriate techniques and establishes the usefulness of SPOT data for urban monitoring.

INTRODUCTION:

Urbanization is a dynamic process, constantly encroaching upon the agricultural lands in the periphery leading to the growth of urban sprawl that are often unplanned. Urban planning requires monitoring the land use changes in the urban fringe. One effective means of acquiring informations needed for urban monitoring is through remote sensing since it provides repetitive and real time data. Previous study of the Madras area using Landsat Multi Spectral Scanner (MSS) data reveals that classification of urban classes was unsatisfactory not only because of low spatial resolution but also because of insufficient separability of the small-sized heterogeneous land use classes (Nagarathinam, 1985). The preparation of thematic maps for urban areas will require the use of image data with resolutions of 5 to 10 m (Welch, 1982). The increased spatial resolution of SPOT data compared to that of Landsat MSS and Thematic Mapper (TM) imagery provides increased interpretability of urban and suburban features thereby increasing the feasibility of urban area delineation and change detection, urban monitoring, areas of urban expansion and by identifying suitable areas for further development. Colwell and Poulton (1985) demonstrated better interpretability of urban/suburban features on the simulated SPOT imagery compared to that on the MSS and TM imagery. Khorram et.al, (1987) and Haack (1987) have assessed and compared the suitability of MSS and TM data for urban land use classification. Such a study ideally needs a multi stage approach i.e., use of different kinds of data in conjunction, however the present study is restricted to the high resolution satellite data to assess the usefulness in urban monitoring.

STUDY AREA DESCRIPTION:

Madras is a port city and an administrative capital of the State of Tamil Nadu, India. The city was founded in 1639 and had grown from a small fishing village to the present size through conurbation process. It is located in the fertile deltaic plain of river Palar. The undulating alluvial plain is strewn by innumerable nonperennial tanks and is drained by disjointed distributaries of Palar. Climatically the area falls under semi-arid regime. The coast is an emergent type with a long beach and a stretch of sand dunes in the south and an area exposed to marine erosion in the north. Madras city and its adjoining suburbs including 48 towns forms Madras Urban Agglomeration which occupies an area of 571.9sq.km. Madras Metropolitan Area extends over an area of 1167 sq.km which includes 306 villages. The urban population is growing at a rate of 4.5% per annum, necessitating an addition of about 35,000 new households annually. To meet this need, urban expansion has taken place into the agricultural interface along the transportation corridors and has proceeded unevenly mostly over unsuitable terrain.

MATERIALS AND TECHNIQUES:

For this study the SPOT Multispectral data (20m) (Scene ID:S1H1860322052339) data was used for identifying urban classes and a comparison was carried out using Landsat TM data (30m) (Scene ID:T511420518671201).

Urban classes were divided into ten categories following the USGS system (Anderson et al.,1976) in such a way that all the classes form the most important part of the urban analysis (Table I). The ground truth informations were collected for these classes. After identifying the training set areas, classification statistics were generated. Seperability analysis was done to check for the spectral seperability between the classes. As the urban classes chosen for this study are spectrally very close in nature integration of ratioed data with original data as an additional band was attempted and statistics were computed to identify the spectral seperability between classes in various bands. This analysis was done for both the SPOT and TM data.

All the multispectral bands of SPOT and all the bands of TM except the thermal band were used to classify the scene and the accuracy was checked again. For the SPOT data a ratio of band 3/2 was added as an additional band to that of 1,2 and 3 and the classification was repeated with the integrated data in order to increase the classification accuracy of high density areas. A ratio of band 7/4 was integrated with bands 2,5 and 7 as an additional band and the classification was repeated so as to discriminate the vegetation pixels from the low density residential areas. Both the original and integrated data of SPOT and TM were used to classify the study area with the above ten classes. The statistical parameters of the training sets were used to classify the scene with the maximum likelihood classifier.

To remove the loss caused by cloud and shadow coverage topographic maps were utilised. After classifying, necessary ground checks were made to assess the accuracy of the resultant output.

RESULTS AND DISCUSSION:

The following urban land use zones are identified from the analysis of both SPOT and TM data(Figs 1-4). The high density core of the city consisting of the Central Business District (CBD) mixed with residences is clearly shown as a separate class. Within this zone an inner core corresponding to the CBD and an outer zone mixed with street houses is also identified based on the knowledge of the area. Around this zone is the low density built up area which is divisible into three zones. The innermost ring immediately next to the high density core is seen to have mixed with vegetation. This is an area of old, posh and independant houses with spacious gardens contributing signatures of dominant vegetation; yet this grouping is quite useful from urban monitoring point of view, as it has brought out another morphological unit. This is followed by a zone of low density residences and finally the outermost edge of the urban sprawl showing predominantly open spaces. This zonation is shown satisfactorily in the classified original SPOT data however, accuracy improvement is revealed in the classified integrated data. (Table II).

Using the TM data, similar zones are identified and the results are compared to assess their relative usefulness and also the levels of accuracy (Table III). Both the data correspond to the same year with the SPOT imagery, classification accuracy is greater, which was ascertained by superimposing the classified output onto the land use map of the Madras City and as per the inference drawn and ground truth check the areal spread of high density zone is found to be nearer to the existing condition. SPOT panchromatic imagery with 10 m resolution served as a source for ground truth verification rather than for actual classification, especially in the absence of aerial photographs. In the fringe area, not only the available vacant space is identified but also the extent and direction of urban growth is traced. Such an analysis when periodically carried out will enable the change detection and updating for urban monitoring.

Regarding the other categories, urban classes such as the communication lines have been classified satisfactorily, but most of the railway lines are classified as roads. Here producer accuracy is more in the case of railway but user accuracy is less. However inclusion of both railways and roads in a single class will yield better result. For urban monitoring transportation study is essential, and it would be desirable to extract these linear features alone for route planning. Jayagobi et.al., (1988) have shown that simple linear feature extracted in Landsat TM band 4 gives most of the railway lines suppressing road informations. Substraction of the linear feature extracted in Band 3 from linear features extracted in Band 4 gives the railway features alone. A

superimposition of these linear features over the land use map produced with the classification system may offer better accuracy and a good map especially for urban monitoring. Areas of solid waste dumps are clearly classified with equal clarity in both original and integrated data. Beach is also classified with greater accuracy. Water features such as rivers and tanks are classified with good accuracy; however some of the stagnant water is also classified as river.

When a comparison is made between the SPOT and TM data, it is found that the classified data of SPOT clearly increased the accuracy in the high density area due to the improved resolution which eliminates the boundary pixel misclassification. In the case of linear features such as roads, railways and rivers greater accuracy is indicated with SPOT data, however, vegetation class showed lesser accuracy in TM. The accuracy can be improved by a simple band ratioing of 2/3 and integrating this transformed data with the original data as an additional band for classification. This classification yields better accuracy in the case of vegetation. However, with this data most of the railway lines are classified as open spaces affecting the user accuracy in the classified map. To avoid this drawback superimposition of linear features as suggested for TM data will offer better user and producer accuracy for SPOT data products. Here also the stagnant water pixels are again classified as river pixels. This suggests the addition of stagnant water as a class will improve the accuracy. River should be marked from the linear feature map generated from the SPOT data and superimposing this river feature with the classified map will improve the user and producer accuracy.

Thus the product yielded from SPOT data with better accuracy may be more useful for urban monitoring. The additional analysis steps suggested are useful in increasing the accuracy over the actual classification system especially for urban monitoring. The separation between the water bodies i.e., between stagnant water and river is most important due to the fact that generally places of stagnant water can be used for different development processes in urban planning. In the case of Madras city, owing to the physiographic nature of the terrain, the densely populated areas along the coast which are old lagoon sites lying below sea level, are susceptible for flooding after monsoon rains. Similar situation exists in the old tank beds which have been converted into residential areas and also along the river banks. Since the rainy season is short, this hazard is overlooked during the dry periods and residential development has proceeded inspite of the poor water quality of the ground water in such areas. Therefore, it is essential to delineate this class for planning purposes. Similarly, it is very much important to classify urban class in the fringe area as this will be more useful in change detection, urban area delineation and for urban growth direction prediction. Temporal classifications and their superimposition can be used for generating difference map to identify the direction of urban growth.

CONCLUSION:

The usefulness of the high resolution satellite data for urban monitoring has been demonstrated in this paper. Extraction of urban classes using SPOT data has been shown to be of value and an increase in accuracy has been achieved by integrating data from different bands. Toll and Kennard (1984) and Welch (1985) have reported similar accuracy in their analysis using simulated SPOT data. In this study, it has also been shown that further increase in classification accuracy can be achieved by integrating ratioed band as an additional band. Because of its high resolution, SPOT imagery is also found to be useful for visual analysis in delineating urbanized areas.

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Table 1 - LAND USE CATEGORIES

Tank
 Road
 River
 Vegetation
 Low density Built-up areas
 High density Built-up areas
 Railway
 Open Space
 Wastedump
 Beach

Table II - CLASSIFICATION ACCURACY OF SPOT DATA

CLASS NAME	ORIGINAL		INTEGRATED	
	PRODUCER ACCURACY	USER ACCURACY	PRODUCER ACCURACY	USER ACCURACY
	%	%	%	%
Tank	100.0000	93.33334	110.000	94.7368
Road	54.54546	78.26087	47.368	72.00
River	94.73685	90.00000	94.736	90.00
Vegetation	60.00000	64.86486	61.538	68.571
Lowdensity	62.85714	57.89474	68.571	60.000
Highdensity	89.65517	89.65517	90.000	87.096
Railway	75.00000	54.54546	50.000	37.500
Open	72.41379	75.00000	79.166	73.076
Wastedump	90.00000	85.71429	90.000	90.000
Beach	95.00000	86.36364	95.000	90.476
OVERALL ACCURACY	75.29412%		73.946%	

Table III - CLASSIFICATION ACCURACY OF TM DATA

CLASS NAME	ORIGINAL		INTEGRATED	
	PRODUCER ACCURACY	USER ACCURACY	PRODUCER ACCURACY	USER ACCURACY
	%	%	%	%
Tank	100.0000	94.73685	100.00	90.00
Road	47.05882	66.66667	46.153	75.000
River	90.00000	90.00000	94.736	90.000
Vegetation	50.00000	48.78049	75.000	73.333
Lowdensity	42.85714	43.90244	65.853	62.790
Highdensity	80.00000	82.75862	80.000	85.714
Railway	68.75000	47.82609	61.538	33.333
Open	67.85714	67.85714	71.428	76.923
Westedump	90.00000	90.00000	90.476	90.476
Beach	94.73685	81.81818	95.00	86.363
OVERALL ACCURACY	67.415%		74.725%	

CLASSIFIED DATA
SPOT-Multispectral

Fig.1 Original.(MADRAS CITY)



Fig.2 Integrated. (512x512)

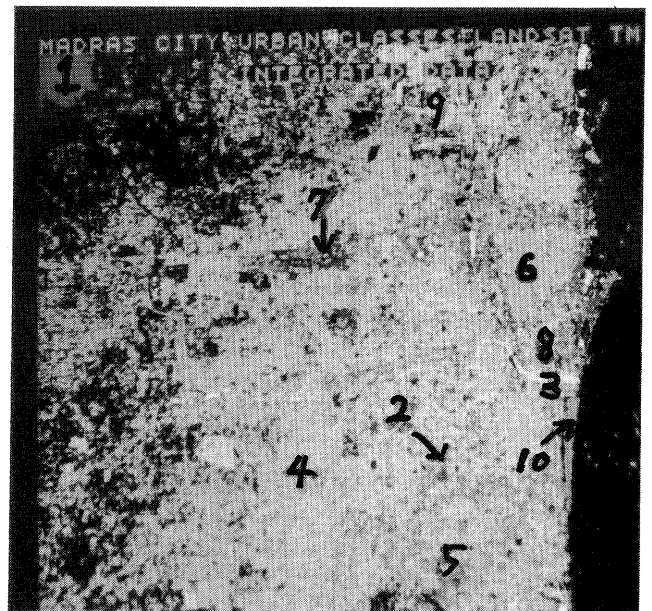


Landsat TM

Fig.3 Original(MADRAS CITY)



Fig.4 Integrated (MADRAS CITY)



LEGEND:

- | | |
|------------------------------|-------------------------------|
| 1. Tank | 6. High density Built-up area |
| 2. Road | 7. Railway |
| 3. River | 8. Open space |
| 4. Vegetation | 9. Wastedump |
| 5. Low density Built-up area | 10. Beach |