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Hybrid Image Classification Technique for Spatio-temporal Analysis of Pune City

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Abstract

Classification techniques in remotely sensed image interpretation are based on spectral reflectance values with an assumption of the training data being normally distributed. Hence it is difficult to add ancillary data in exiting classification procedures to improve accuracy. In hybrid classification technique, integration of Geographical Information System and remote sensing data has become important techniques for change detection applications. This paper emphasizes on a hybrid image classification approach for remotely sensed images obtained from various sensors viz. IRS LISS-II and LISS-III are used. The proposed classification approach effectively integrates ancillary information into the classification process and combines ISODATA clustering, rule-based classifier and the Multilayer Perceptron (MLP) classifier which uses artificial neural network (ANN) that produce higher accuracy classified map. This technique has been applied to produce high accuracy map of Pune city.

Keywords: *Hybrid Classification, GIS, Remote Sensing, Spatial-temporal Analysis*

Introduction

India is the second largest country after China in population and is projected to cross China's population with 1.5 billion people by 2040.The urban population in India increased from 62.4 million in the year 1951 to 377.1 million in 2011. It is estimated to grow to around 540 million by the year 2021. To sustain this rapid urban development should be planned in a sustainable manner to fulfill all the utility services like infrastructure, transportation, water supply, sanitation and drainage etc. urban developers, planners and administrators should have knowledge of the present trend of urbanisation. Therefore there is need to understand the pattern of built-up land over period of time using advanced techniques of remote sensing and geographical information system.

The spatio-temporal change detection analysis includes the integration of GIS and remote sensing methods and the output in pure GIS platform. The advantage of using GIS is the ability to incorporate different source data into change detection applications (Lo and Shipman, 1990). In recent years, incorporation of multi-source data (e.g. aerial photographs, TM, IRS and previous thematic maps) has become an important method for land-use and land-cover (LULC) change detection (Mouat and Lancaster 1996, Salami 1999, Salami et al. 1999, Reid et al. 2000, Petit and Lambin 2001, Chen 2002, Weng 2002). Especially, when the change detection involved long period intervals associated with different data sources, formats and accuracies or multi-scale land-cover change analysis (Petit and Lambin 2001). Weng (2002) has used the integration of remote sensing, GIS and stochastic modelling to detect land-use change in the Zhujiang Delta of China and indicated that such integration was an effective approach for analysing the direction, rate and spatial pattern of land-use change. Yang and Lo (2002) has used an unsupervised classification approach, GIS-based image spatial reclassification and post-classification comparison with GIS overlay to map the spatial dynamics of urban land-use/land-cover change in the Atlanta and Georgia metropolitan area.

Most previous applications of GIS and remote sensing methods in change detection analysis were focused on urban studies. This is probably because traditional change detection methods often have poor change detection results due to the complexity of urban landscapes, coarse resolution and also these techniques could not efficient to use multi-source data analysis.

Study Area

Pune city lies between latitudes 18° 25'N and 18° 37'N and longitudes between73° 44'E and 73° 57'E and cover an area of 250.56 sq km with a population of over 3 million composed of 76 general electoral wards. On the basis of 2011 census, these wards were converted in 14 administrative wards by Pune Municipal Corporation (PMC).

Pune city is located at an altitude of 560m above mean sea level. The city is bounded by Thane district to the north-west, Raigad district to the west, Satara district to the south, Solapur district to the south-east and Ahmednagar district to the north and north-east (Fig 1).

Pune has emerged as a prominent location for manufacturing industries, and has now been recognized as the information technology hub and education hub of the country. The rapid growth of the city has transformed from its character as Pensioner's city to Educational – Administrative Center and now to a bustling economic center.

Problem Definition

Chang detection analysis of land use / land cover classes are not easily separated using spectral brightness values and difficult to add ancillary data in classification procedures.

This work is motivated and guided by the research need to apply a new classification technique for higher accuracy. The proposed classification approach is effectively integrates ancillary information into the classification process.

Research Objectives

The main objectives of the present paper are:

- To identify existing land use and land cover of study area.
- To study changing pattern of built-up area using hybrid classification technique.

Methodology

The complexity of a dynamic phenomenon such as urban growth could be understood with the analysis of land use/ land cover changes. At the first toposheets shown in Table 1 were scanned and geo referenced using WGS 1984 UTM Zone 43N Projection. Various GIS layers such as built-up area, roads and railway network, contour, drainage network and administrative boundaries from Survey of India toposheets were digitized using Arc GIS 9.3 software.

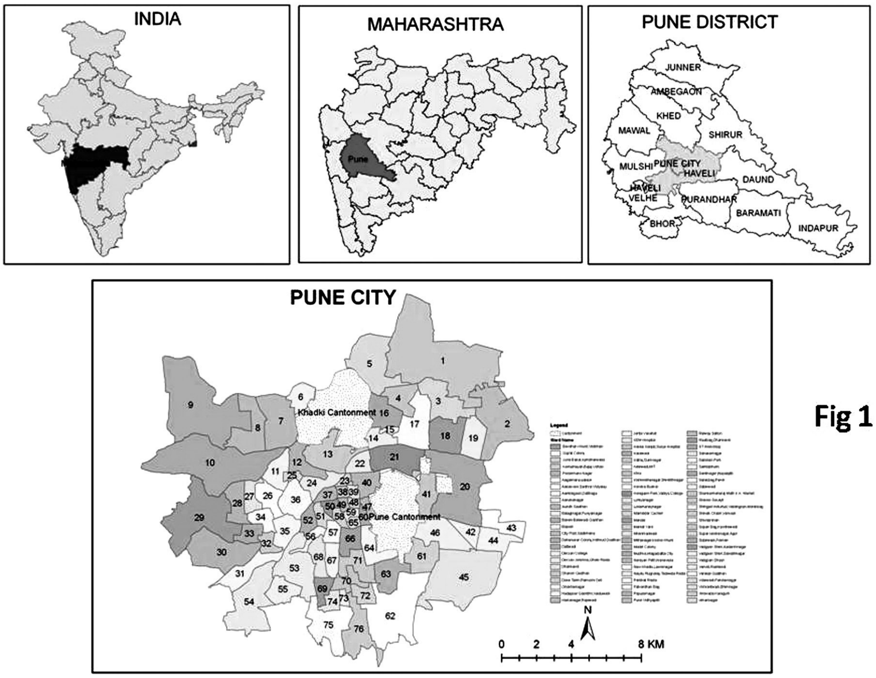

Fig 1

Land cover and land use analyses were done by using remote sensing data. The change detection analysis observed over a period of four decades (1970-2008) was determined by computing the area of the settlements pattern from toposheets of 1970 and comparing it with the area obtained from the classified satellite images for the built-up area.

The detailed methodology followed is described in the flow chart (Fig. 2). In this study remotely sensed images obtained from various sensors viz. IRS-1B (LISS-II) and IRS-P6 (LISS-III) are used. Satellite image was procured from National Remote Sensing Centre (NRSC), Hyderabad for the years 1992 and 2008. The image obtained from NRSC was geo-registered with respect to the Survey of India toposheets.

Initially, the standard image processes for the analysis of satellite data such as rectification, enhancement, band extraction, restoration and classification were completed. Supervised classification approach was adopted as it was found more accurate compared to unsupervised classification. The hybrid image classification approach was employed with for the image classification using ERDAS 9.3 software. The original classification of land use and land cover of 12 categories was aggregated using hybrid classification approach to six major classes such as Agriculture, Forest, built-up (residential & commercial), Scrublands, fallow lands, and water bodies.

Area under built-up (residential & commercial) after classification was extracted from classified images, which gave the urban area for year of 1992 and 2008. Further, by overlaying the layer of built-up area (1970-2008) with the layer of city boundary. The built-up area under wards for the region was computed for change detection.

Data Collection

The data collection involved collection of toposheets, ward maps, satellite data and demographic details. The nature of these data and their source are shown in Table 1. The Survey of India toposheets of 1:25,000 scale was used for the current study of the following features:

- Drainage, water bodies;
- Contours;
- Built-up area;
- Roads and rail network; and
- Administrative boundaries.

Other data sources are satellite images of Pune city (IRS 1 B LISS-II (1992) and IRS P6 LISS- III of 2008), various maps collected from published materials and from related web sites.

Field Work

Field work is important step ground truth of the results to understand the land use / land cover change of study area. This step indicates the visit to the study area in different time or seasons using Global Poisoning System (GPS) surveys and digital photographs. That helped to understand the existing land use / land cover and the actual changes that took place in the study area from 1970 to 2008.

Table 1: Primary and secondary data details for the study area

Segment : Pune City	**Sources**
Toposheets No. 47F/14/1 to 47F/14/6 F/15/NE, F/15/NW and 47F/15/SE	Survey of India, scale 1:25000
Google Image	Internet
Satellite Imagery - LISS III; Path: 100 Row: 64 & Path: 99 Row: 65	National Remote Sensing Center (NRSC), Hyderabad
Demographic details from Primary Census abstracts for, 1991 , 2001 and 2011	Directorate of census operations, Census of India
All Secondary data (Demographic, Landuse/ Landcover etc.)	City Development Plan **[CDP]** (2006-2012)
Ward map and Administrative Boundary	Pune Municipal Corporation (PMC)

Result and Discussion

Land Utilization:

The first town planning scheme was prepared for Shivaji Nagar in 1918 and a Master plan was prepared in 1952 for the Poona city. The first Development Plan (DP), for PMC was prepared in 1966 (10 year horizon till 1976) in accordance with the new legislation that is the Maharashtra Town and Country Planning Act, 1966. Revision was made in 1982 which was sanctioned by the GoM in 1987. The second DP was prepared for horizon of 20 year (to be valid till 2007) for PMC area of 138.36 sq. km. In 2001, PMC jurisdiction was extended by merging 23 neighboring villages (in parts) and DP was exclusively

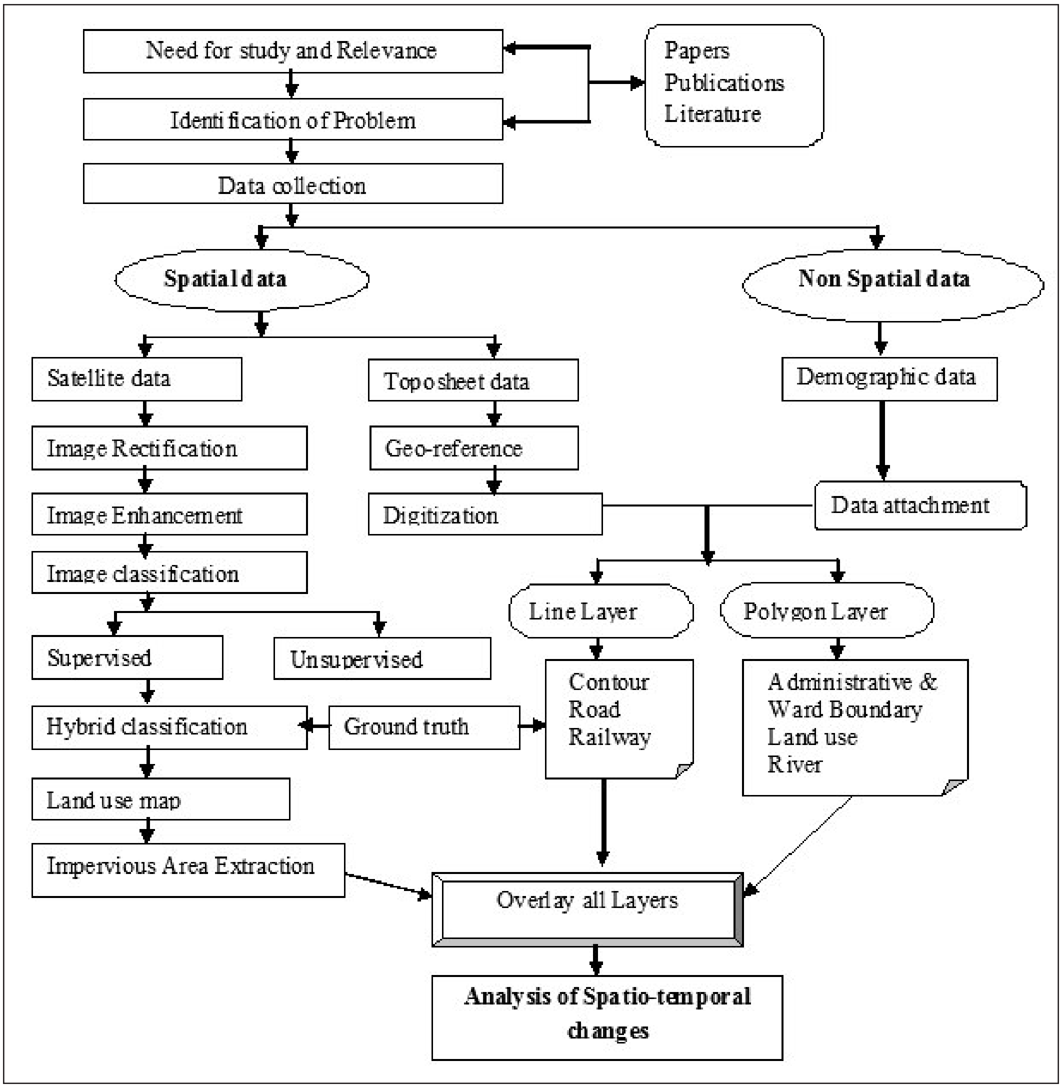

Fig. 2 : Flowchart of Methodology

prepared for this fringe area for a horizon of 20 years (valid till 2021). The combined percentage distribution for various land utilization categories is presented in the Fig. 3. It is evident that the developed area is almost 70 % of the total land utilization leaving only 30 % for ecological resources. The percentage of green area and forest adds together to 20%.

Built-up area from Toposheets (1970):

The built-up area for 1970 was extracted from the digitized SOI toposheets scale of 1:25,000 and is shown in fig 4 (see page 210). Then built-up area was computed by overlaying the layer with administrative boundaries and added to the attribute database for further analysis.

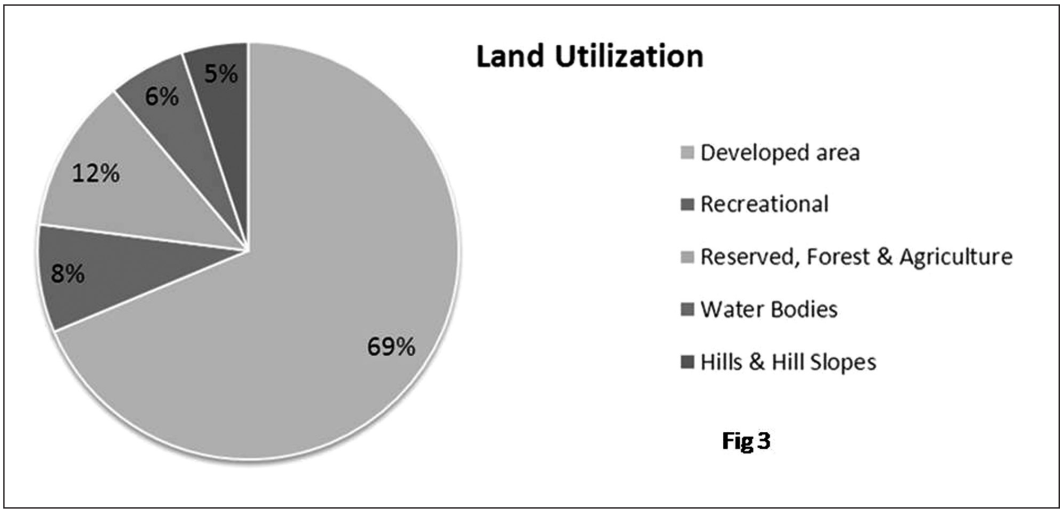

Fig. 3 Land Utilization PMC (1987 DP +2001 DP) *(Source: Revising CDP of Pune city-2041)*

Built-up area from Satellite Images (1992 & 2008):

Land use / land cover classes that are not easily separated using spectral brightness values, ancillary data have often been used. Ancillary data such as elevation, slope, aspect, soil, and hydrology have been incorporated directly into hybrid classification.

The methodology for the hybrid classification considered three different classifiers that are commonly used in remote sensing image classification i.e. knowledge based (expert) classification, unsupervised and a non- parametric classifier, multi-layer perceptron (MLP) that utilizes artificial neural network. The approach was to combine the three classifiers to classify the satellite image data with ancillary geo-spatial data and form a multiple classifier system which combined the relative strengths from the different classifiers and applied them in a sequence in such a way that the overall accuracy was the maximized.

First, a knowledge based classification was applied after gathering knowledge in the form of hierarchical rule set. Then, the pixels that were not being classified by the rules were masked out and an ISODATA clustering was applied to classify those pixels and then they were merged with the previous classified pixels. A MLP classifier with two hidden layers was applied which took the three or four bands of IRS image. Finally those classes of each classifier having higher kappa values were merged together to get the final classified image.

Fig. 5 (see page 211) the classified satellite images of Liss-II and fig. 6 (see page 211) Liss-III are classified by using the hybrid classification method. Binary maps of urban extents showing land use/ land cover classes were extracted from the classified images. Land use/land cover layers of 1992 and 2008 showing six classes named as agriculture, settlement, river and lakes, vegetation, fallow land and scrub land have been prepared with the help of classified images.

Accuracy Assessment

To check the accuracy of the land use / land cover classification with ground truth data before it can be used in scientific investigations and decision making policies (Jensen, 2005). The results of the accuracy assessments were used to compare the results of the different classification techniques. A stratified random sampling technique was applied for collecting the ground truth data for accuracy assessment. In this technique a minimum number of samples are selected from each class and samples are allocated to all the classes for accuracy assessment without depending on the proportion of each individual class in the entire study area. Sample data (pixels) collected for two ways, one for training base and the other for testing.

Overall Accuracy:

The overall accuracy is determined by the sum of all samples on the diagonal (total correct pixels) divided by the total number of samples. Table 2 and 3 shows the overall accuracies for each of the three different classifiers.

Table 2 : Comparison of overall accuracies for the three different classifiers of LISS-II Classified Satellite image (1992).

Classifiers	Total number of pixels	Number of correct pixels	Overall accuracy %
Unsupervised ISODATA clustering	75	54	72.00
Supervised classification with Feature Analyst	75	49	65.33
Proposed Hybrid Classifier	75	61	81.33

Table 3 : Comparison of overall accuracies for the three different classifiers of LISS-III Classified Satellite image (2008).

Classifiers	Total number of pixels	Number of correct pixels	Overall accuracy %
Unsupervised ISODATA clustering	90	65	72.22
Supervised classification with Feature Analyst	90	61	67.78
Proposed Hybrid Classifier	90	73	81.11

Table 2 shows LISS-II (1992) classified satellite image represent the hybrid classifier had the highest overall accuracy rate of 81.33% (61 correct pixels out of 75) in comparison to unsupervised ISODATA clustering (72.00%; 54 out of 75) and supervised classification with Feature Analyst (65.33%; 49 out of 75), having the lowest overall accuracy.

Table 3 shows LISS-III (2008) classified satellite image represent the hybrid classifier had the highest overall accuracy rate of 81.11% (73 correct pixels out of 90) in comparison to unsupervised ISODATA clustering (72.22%; 65 out of 90) and supervised classification with Feature Analyst (67.78%; 61 out of 90), having the lowest overall accuracy.

The Kappa Statistic:

Accuracy assessment which uses K_{hat} statistic as a measure of agreement or accuracy between classified map and reference data (Jensen, 2005). K_{hat} uses the major diagonal elements of the error matrix and the chance agreement indicated by the row and column totals (marginals), thus considering interclass agreement. K_{hat} statistic is computed as (Jensen, 2005, Congalton, 1991):

$$K_{\text{hat}} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{k}(x_{i+} * x_{+i})}$$

where k is the number of rows in the matrix, *xii* is the number of observation in row *i* and column *i*, and *xi+* and *x+I* are the marginal totals for row *i* and column *i*, respectively, and *N* is the total number of observations.

Kappa coefficient ranges between

Table 4: Comparison of the kappa values for the three classifiers

Classified Satellite Image	Unsupervised ISODATA clustering	Supervised classification with Feature Analyst	Proposed Hybrid Classifier
LISS-II (1992)	0.62	0.57	0.73
LISS-III (2008)	0.64	0.59	0.74

0-1 and a negative kappa is an indicator of very poor classification (Lillesand et al., 2004).

Table 4 shows comparison of the proposed hybrid classifier with two other standard classification techniques: unsupervised ISODATA clustering and supervised classification with Feature Analyst, a comparison between 1992 and 2008.

The overall kappa values (Table 4) also suggest that the proposed hybrid classifier 0.73 (LISS-II) and 0.74 (LISS-III) are superior to unsupervised ISODATA clustering and supervised classification with Feature Analyst.

This research showed that using the hybrid classification technique to classify IRS data to achieve higher classification accuracy than other classification techniques used in this area.

Comparison of Built-up area of Pune city from 1970-2008:

The land use / land cover changes were studied from Survey of India toposheets and LISS II and III satellite image. The study mainly concentrated on the built-up area, since that was considered as prime indicator of urban development. The built-up area of 1992 and 2008 from satellite image was converted raster into vector data set in Arc GIS software and was compared with the toposheet of 1970-71.

Fig. 7 demonstrated the trend of built-up area of Pune during 1970 was just 13.60 km² and in 2008, it was 72.63 km².

However, the result of the table 5 shows a rapid growth in built-up land between

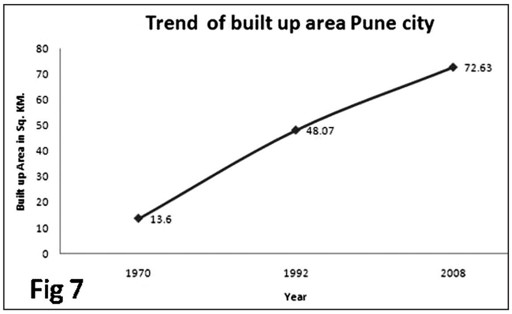

Fig. 7 Trend of built up area from 1970 to 2008

1970 to 2008.The development has been compared with built-up area of Pune city.

Table 5 : Trend of built up area of Pune city

Classes	Year	Built up Area in Sq.km.
SOI Toposheet	1970	13.60
Liss II Satellite Image	1992	48.07
Liss III Satellite Image	2008	72.63

Fig. 8 (see page 212) shows theme map was overlaid on toposheet and the satellite image (1992 and 2008) for the change detection analysis. The changes, which were observed in the land use pattern, confirmed the urban expansion along the fringe areas. The analysis revealed that almost 75-85% of open land was brought under urban land use. Most of the vacant lands close to the roads are converted for residential purpose or are under construction. In between some vacant lands are occupied with brick kilns, marble stockyards and stone quarries. The open lands located inside the city, were mostly converted into big shopping Malls or hotels. The open areas, close to the outskirts of the city, are mostly turned into big townships, new colonies, Institutions and apartment complexes. The land use indirectly reflects the land values, as the prices in the fringe areas are much lower than the areas near the central areas of the city (Shekhar S.2005). Presently the land values are increasing along the urban fringe areas due to great demand.

Conclusion

The outcome of hybrid classification techniques has been revealed that change detection study of land use/ land cover analysis appropriately classify different land use classes with high accuracy as compare to existing classification techniques. Hence the hybrid classification techniques may be suitable while studying aspect related to urban sprawl, urban utility services, urban infrastructure development and studies related to sustainable urban planning.

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References

Carpenter, G. A., Gjaja, M. N., Gopal, S., & Woodcock, C. E. (1997). ART neural networks for remote sensing: vegetation classification from Landsat TM and terrain data. *IEEE Transactions on Geoscience and Remote Sensing, 35*, 308-325.

Census of India, (2011).

Chaudhuri, Debasish, (2008) Hybrid Image Classification Technique for Land-Cover Mapping in the Arctic Tundra, North Slope, Alaska. Ph.D thesis Directed by Dr.Roy Stine. 182 pp.

City Development Plan (CDP) of Pune City from 2006-2012

Congalton, R.G. (1996). Accuracy Assessment: A Critical Component of Land Cover Mapping. In Scott, J.M., Tear, T.H., & Davis, F., (Eds.), *Gap analysis: a landscape approach to biodiversity planning* (pp. 119–131). American Society for Photogrammetry and Remote Sensing.

Desai C.G., Patil M.B., Mahale V.D. and Umrikar B. (2009) Application of remote sensing and geographic information system to study land use / land cover changes: a case study of Pune Metropolis, Advances in Computational Research, ISSN: 0975–3273, Volume 1, Issue 2, 2009, pp-10-13

Environment Status Report of PMC (2001 to 2012)

ERDAS Imagine Field Guide. (2011).

ESRI, ArcGIS Desktop Help. (2010).

Jensen, J. R. (2005). *Introductory Digital Image Processing: A Remote Sensing Perspective.* NJ: Prentice Hall.

Jensen, J.R., Qiu, F. & Patterson, K. (2001). A Neural Network Image Interpretation System to Extract Rural and Urban Land Use and Land Cover Information from Remote Sensor Data. *GeoCarto International, A Multidisciplinary Journal of Remote Sensing and GIS, 16,* 19-28.

Lillesand, M.S, Kiefer, R.W.and Chipman, J. W., (2004) Remote Sensing Image Interpreatation, John Wiley and Sons.

Liu, X.H., Skidmore, A.K. & Oosten, H.V. (2002). Integration of Classification

Methods for Improvements of Land-cover Map Accuracy, *ISPRS Journal of*

Photogrammetry & Remote Sensing, *56,* 257-268.

Lo, C. P., and Shipman, R. L., (1990) A GIS approach to land-use change dynamics detection. Photogrammetric Engineering and Remote Sensing, 56, 1483–1491.

Lu, D. S., Mausel, P., Brondi´Zio, E. S., and Moran, E., (2002) Change detection of successional and mature forests based on forest stand characteristics using multitemporal TM data in the Altamira, Brazil. XXII FIG International Congress, ACSM–ASPRS Annual Conference Proceedings, Washington, DC, USA, 19–26 April (Bethesda, MD: American Society of Photogrammetry and Remote Sensing) (CD-ROM).

Mouat, D. A., and Lancaster, J., (1996) Use of remote sensing and GIS to identify vegetation change in the upper San Pedro river watershed, Arizona. Geocarto International, 11, 55–67.

National Resource Research Institute (1997). Land cover characteristics based on Landsat Imagery. Retreived on July19, 2005, from

www.nrri.umn.edu/toolik/vegetation.html.

Shekhar S.(2005) Monitoring urban sprawl of Pune city by using RS & GIS Techniques., Ph.D thesis submitted to University of Pune.

Singh, A., (1989) Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing, 10, 989–1003.

Skidmore, A.K., Turner, B.J., Brinkhof, W., & Knowles, E. (1997). Performance of a neural network: mapping forests using GIS and remote sensing data. *Photogrammetric Engineering and Remote Sensing, 63,* 501-514.

Stow, D., Coulter, L., Kaiser, J., et al. (2003). Irrigated Vegetation Assessment for Urban Environments. *Photogrammetric Engineering and Remote Sensing, 69,* 381-390.

Sudhira, H. S., & Ramachandra, T. V. Karthik S. Raj And Jagadish K.S. (2003). Urban Growth Analysis Using Spatial and Temporal Data, Journal of the Indian Society of Remote Sensing, Vol. 31, No. 4, 2003

Sulochana Shekhar, Changing space of Pune, A GIS perspective GIS & Development Map world form Hyderabad India paper ref MWFPN 116

Taubenböck H., Wegmann M., Berger C. ,Breunig M. (2008) Spatiotemporal Analysis of Indian Mega Cities, *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B2. Beijing 2008*

Petit, C. C., And Lambin, E. F., (2001) Integration of multi-source remote sensing data for land cover change detection. International Journal of Geographical Information Science, 15, 785–803.

Updating City Development Plan (CDP) of Pune City – 2041

Van Genderen, J. L. and Lock, B. F. (1976) Testing Land-use map Accuracy. Photogrammetric Engineering and Remote Sensing, 43 (9): 1135-1137

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