OBJECT-ORIENTED IMAGE PROCESSING OF AN HIGH RESOLUTION SATELLITE IMAGERY WITH PERSPECTIVES FOR URBAN GROWTH, PLANNING AND DEVELOPMENT

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Abstract

The management of urban areas by urban planners relies on detailed and updated knowledge of their nature and distribution. Manual photo-interpretation of aerial photographs is efficient, but is time consuming. Image segmentation and object-oriented classifications provide a tool to automatically delineate and label urban areas. Here single pixels are not classified but objects created in multi-resolution segmentation process, which allows use of, spectral responses but also texture, context and information from other object layers. This paper presents a methodology allowing to derive meaningful area-wide spatial information for city development and management from high resolution imagery. Finally, the urban land cover classification is used to compute a spatial distribution of built-up densities within the city and to map homogeneous zones or structures of urban morphology.

Key words: Object oriented, Classification, Segmentation, Spatial information, Accuracy assessment, Urban morphology

1. INTRODUCTION

Human land use decisions on the environment are influenced by socioeconomic factors which can be represented by spatially distributed data. The accelerating urban sprawl, often characterized by a scattered growth, has rarely been well planned, thus provoking concerns over the degradation of our environmental and ecological health[2]. Up-to-date and area-wide information management in highly dynamic urban settings is a critical endeavor for their future development. Thematic assessments of urban sprawl involve procedures of monitoring and mapping, which require robust methods and techniques[3]. Conventional survey and mapping methods cannot deliver the necessary information in a timely and cost-effective mode. Limited spatial information within the built-up zone hinders urban management and planning. Especially in growing and altering cities lack of up-to-date data is apparent. The challenge of classifying urban land cover from high resolution remote sensing data arises from the spectral and spatial heterogeneity of such imagery. There to the high dissimilarity of functions like industrial or residential areas as well as parks or agricultural regions causes problems in terms of an indirect inferring of land use [7,8].

2. STUDY AREA, METHODOLOGY AND RESULTS

2.1 Study Area

The study site, Vijayawada city, known as the political capital of the State, located in the south-east of India is the third largest city of Andhra Pradesh state. Vijayawada is located on the banks of the sacred Krishna River and is bounded by the Indrakiladri Hills on the West and the Budemeru River on the North.

The other details of Vijayawada city are given in Table 1.

Table 1: Details of Vijayawada city

1)State	Andhra Pradesh	6)Time zone	IST (UTC+5:30)
2)District	Krishna	7)Population	10,35,536
3)Coordinates	16.30° N 80.37° E	8)Density of Population	17,854 /km²
4)Area	58 km²	9)Postal code	5200xx
5)Elevation	125 m	10)Telephone code	+91 866

2.2 Data

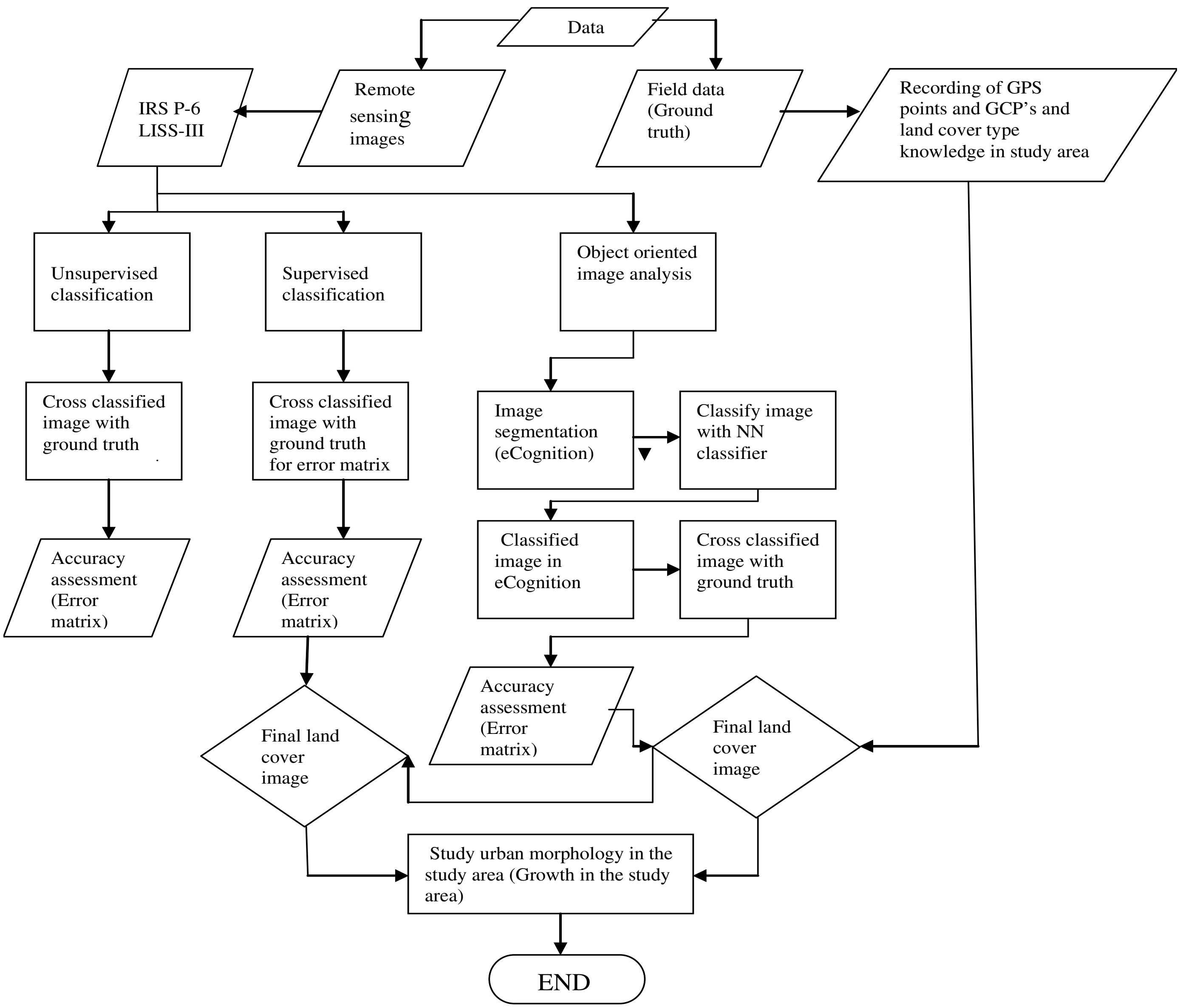
High resolution multispectral IRS P-6 LISS-3(Band 2,3,4 &5) images were taken. This satellite carries three sensors (LISS-III, AWiFS & LISS-IV) with 5.8m, 23.5m & 56m resolutions and fore-aft stereo capability. The payload is designed to cater to applications in cartography, terrain modeling, cadastral mapping etc., These images were supplied by NRSA, Hyderabad, India.(http://www.nrsa.gov.in)

Global Positioning System (GPS) receiver has been used for ground truth data that records the coordinates for the polygons of homogeneous areas, and also it records the coordinates that will be used for geometric correction. The GPS is in existence since the launch of the first satellite in the US Navigation System with Time and Ranging (NAVSTER) system on February 22, 1978, and the availability of a full constellation of satellites since 1994. The US NAVSTAR GPS consists of a constellation of 24 satellites orbiting the Earth, broadcasting data that allows a GPS receiver to calculate its spatial position (Erdas imagine, 2001).

Ground truth data is used for use in image classification and validation. The user in the field identifies a homogeneous area of identifiable land cover or use on the ground and records its location using the GPS receiver. These locations can then be plotted over an image to either train a supervised classifier or to test the validity of a classification.

2.3 Methodology

Here, the description about the land cover types and their distributions of the study area is given. Except this, the remote sensing images, ground truth used in this study are described in detail and also the data preprocessing before conducting the classification is described. Methodology to perform this research is given in flow chart 1.



Flow chart 1: Methodology

2.4 Results

2.4.1 Unsupervised and Supervised classification

The basic premise for unsupervised classification is that spectral values within a given land cover type should be close together in the measurement space, whereas spectral data in different classes should be comparatively well separated (Lillesand, 2001). Unsupervised classification is fast and has the ability to analyze the image spectral statistics completely and systematically, thus unsupervised classification can give useful indication of detectable classes for supervised classification (Mather, 1987).

Supervised classification result of the study area (Vijayawada city) with different land cover types is presented in Plate 1.

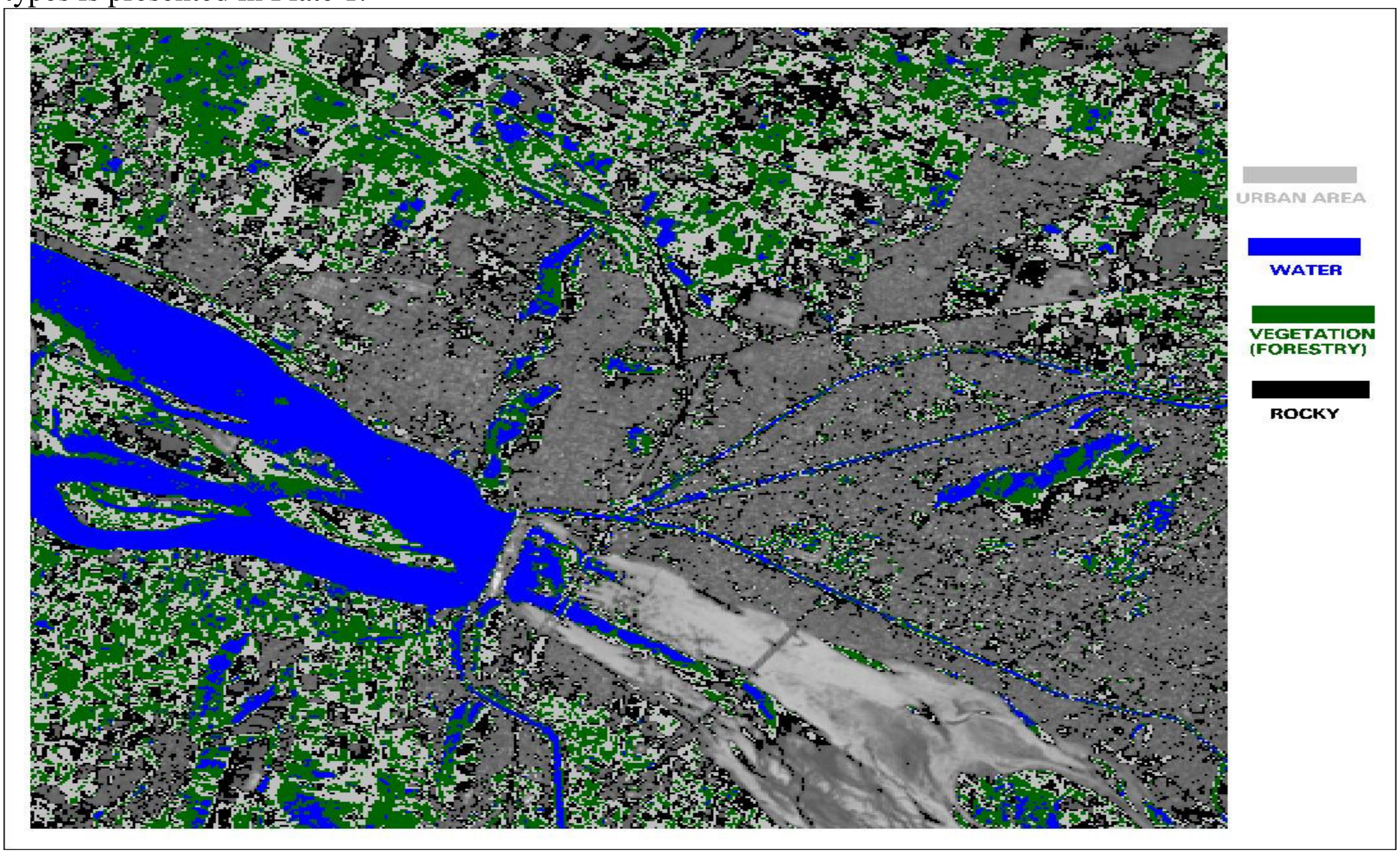


Plate 1: Supervised classification result of Study area(Vijayawada city) from IRS P-6 LISS-III Imagery

2.4.2 Object oriented image analysis

Using the object oriented image analysis approach to classify the image is performed in eCognition. Object oriented processing of image information is the main feature of *eCognition*. The first step in *eCognition* is always to extract image object primitives by grouping pixels. The image objects will become building blocks for subsequent classifications and each object will be treated as a whole in the classification. Multi-resolution segmentation is a basic procedure in eCognition for object oriented image analysis. The segmentation rule is to create image objects as large as possible and at the same time as small as necessary. After segmentation, a great variety of information can be derived from each object for classifying the image. In comparison to a single pixel, an image object offers substantially more information.

2.4.3 Comparison of segmentation results with different scale parameters in the study area

Plate 2 is the original image of the study area. Plates 3, 4 and 5 show the effect of segmentation results using different segmentation parameters. Except scale difference, the other parameters that influence the segmentation result are color, shape, smoothness and compactness but these are kept constant. Plate 3 is the segmentation result with a scale parameter 5.Comparing this segmentation result with the original image, it is found that neighbor pixels are grouped into pixel clusters-objects, and because of the low value of scale parameter, there are too many small objects. Plate 4 is the segmentation result with scale parameter 10. It is found by comparing it with Plate 3 that higher scale parameter value generates larger objects. Plate 5 is the segmentation result with scale parameter 20. By visual comparison, a scale parameter of 10 is selected because the segmentation result fits the information class extraction best. Based on these parameters, segmentation process is performed.

2.4.4 Image classification

Classification is the process of connecting the land cover classes with the image objects. After the process of classification, each image object is assigned to a certain (or no) class. In eCognition, the classification process is an iterative process. The classification result can be improved by editing the result: defining unclassified objects with the correct classes, correcting wrongly classified objects with the correct classes, etc.

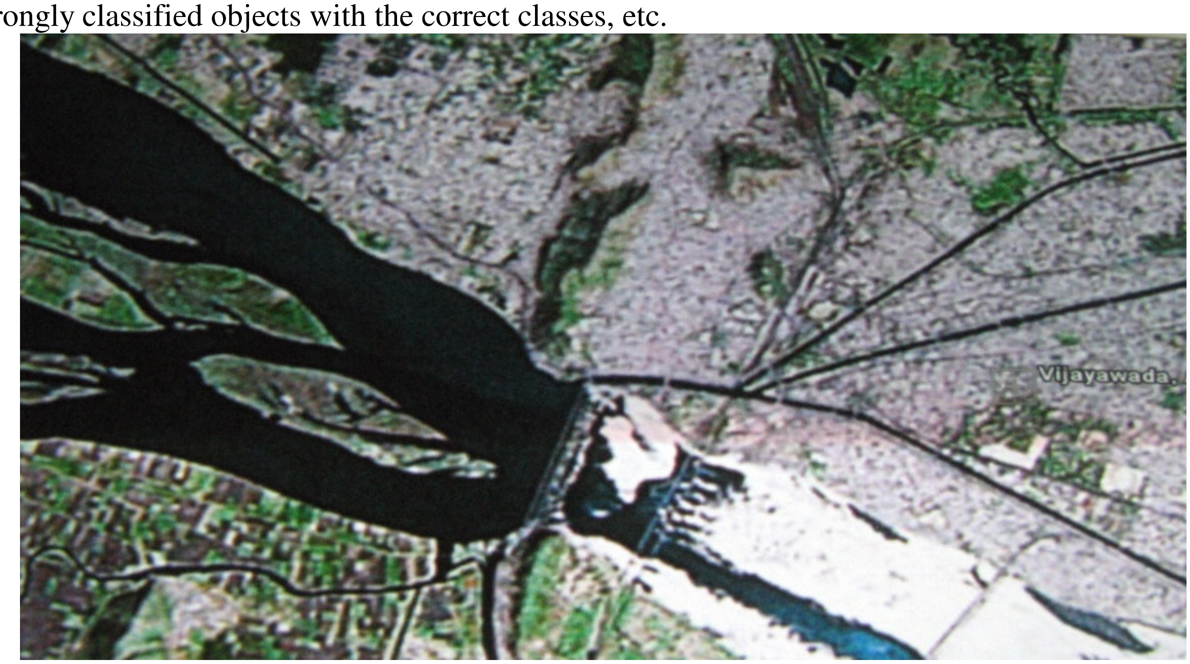


Plate 2: Original image of the study area (Vijayawada city)

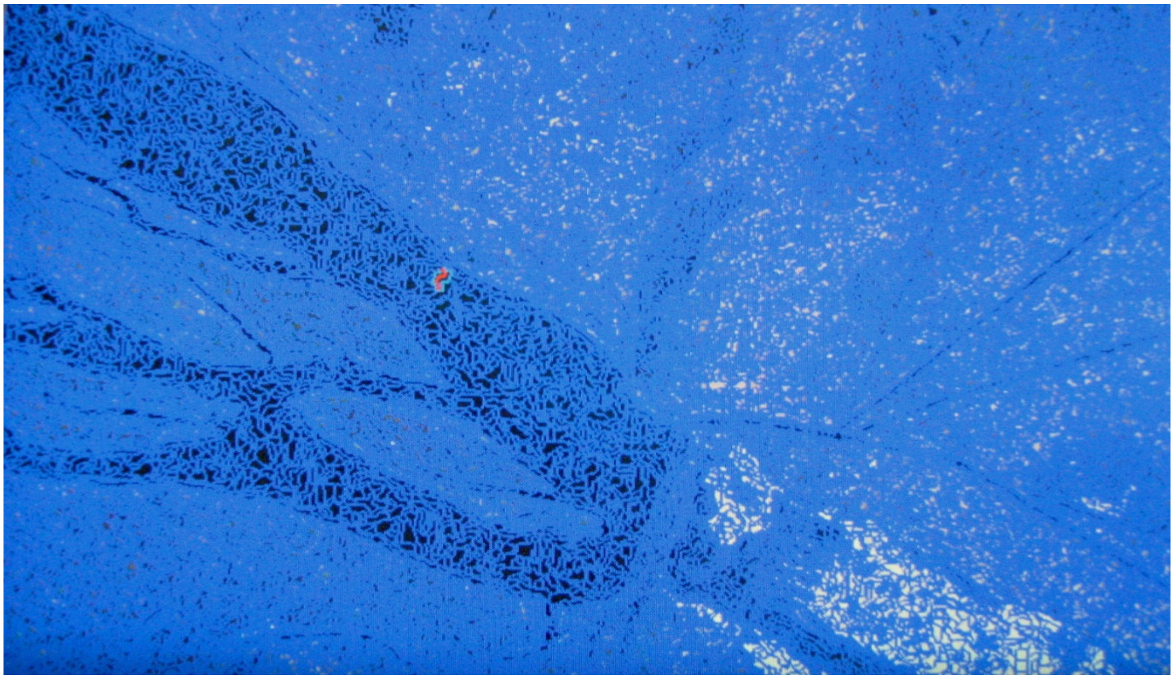


Plate 3: Segmentation result with scale parameter 5, color 0.8, shape 0.2, smoothness 0.9, & compactness 0.1

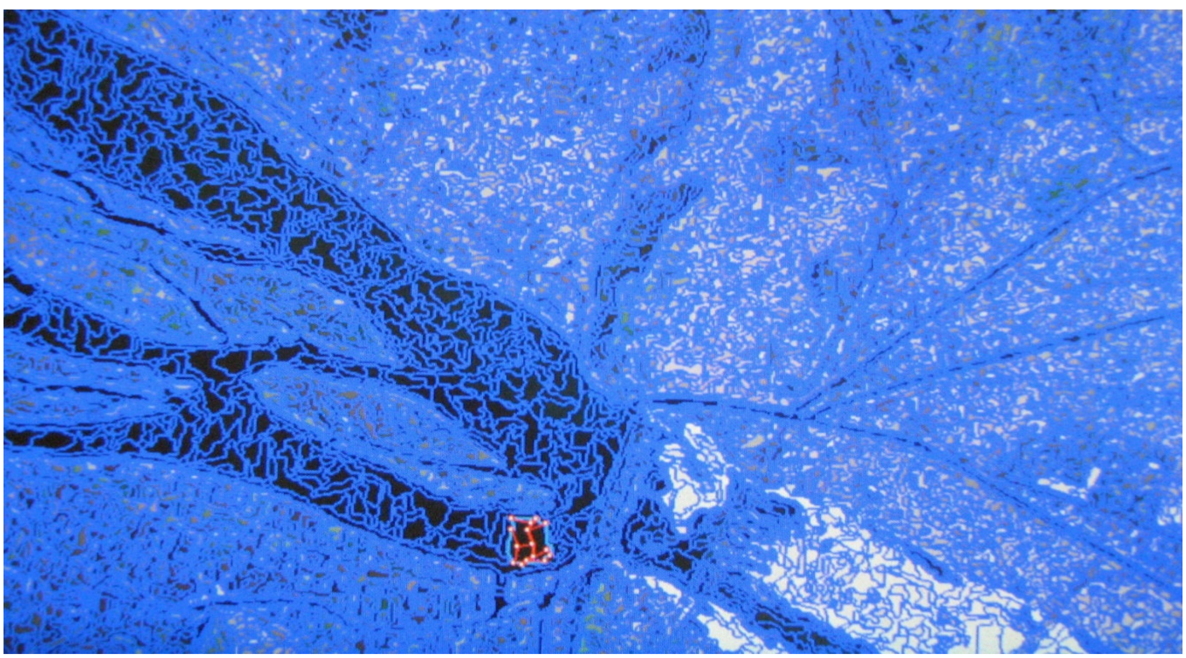


Plate 4: Segmentation result with scale parameter 10, color 0.8, shape 0.2, smoothness 0.9, & compactness 0.1

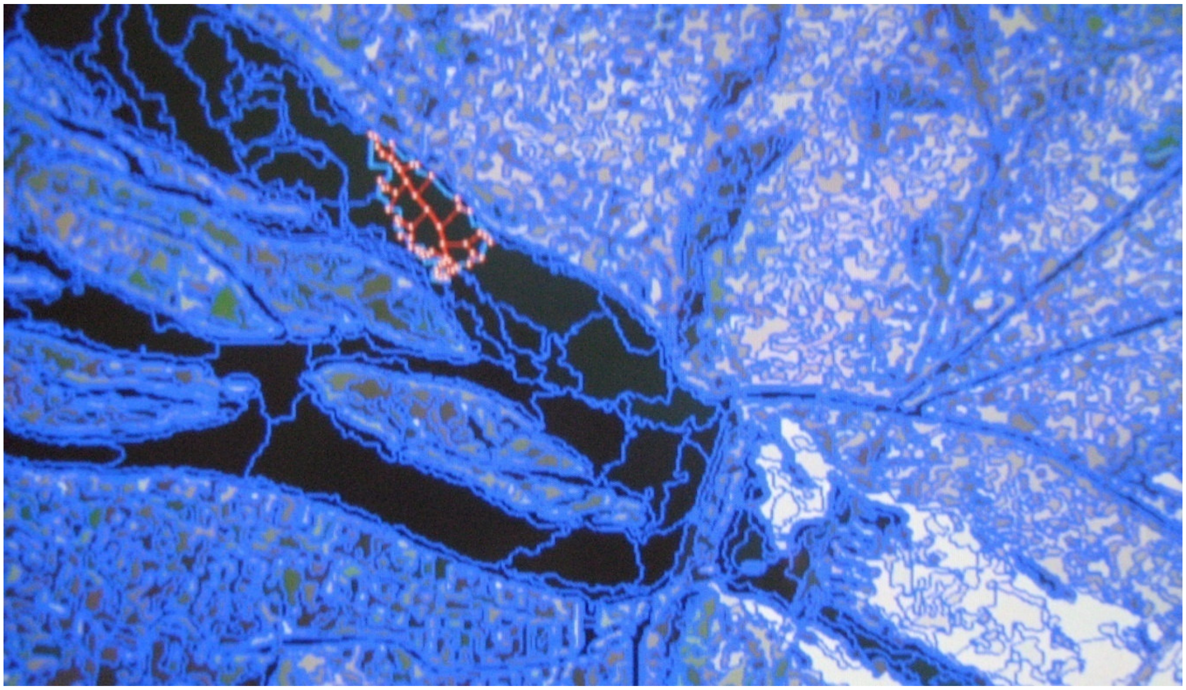


Plate 5: Segmentation result with scale parameter 20, color 0.8, shape 0.2, smoothness 0.9, & compactness 0.1

2.4.5 Accuracy assessment

Accuracy assessment values were generated in eCognition by creating a test area and training mask (TTA) as shown in table 2. The TTA mask contained 52 “Urban,” “Vegetation,” and “rocky” objects and 25 “water” objects. These objects, representing actual land cover were compared against the classified identity of these objects. The “water” class was very accurately classified, and was therefore limited to 25 testing objects in order to reduce its inflationary effect on the accuracy statistics.

Table 2: Error matrix and Accuracy statistics

	Reference data*				
Classification Data	**U.A**	**W**	**V**	**R**	**Total**
U.A	12766	0	0	951	13717
W	5168	59897	0	0	65065
V	0	0	17600	0	17600
R	0	0	1180	30336	31516
Total	17934	59897	18780	31287	127898

*U.A-Urban Area, W-Water, V-Vegetation, R-Rocky

Producer's accuracy can be calculated using the formula:

$$\textbf{PA (class I)} = a_{ii} \div \sum_{i=1}^{n} a_{ki}$$

Producer's accuracy (%):
Urban area=12766/17934=71.18
Water=59897/59897=100
Vegetation=17600/18780=93.7
Rocky=30336/31287=96.9
User's accuracy can be calculated using the formula:

$$\textbf{UA (class I)} = a_{ii} \div \sum_{i=1}^{n} a_{ik}$$

User's accuracy(%):
Urban area=12766/13717=93
Water=59897/65065=92
Vegetation=17600/17600=100
Rocky=30336/31516=96.2

Over all accuracy can be calculated using the formula:

$$\text{OA}=\sum_{k=1}^{n} a_{kk} \div \sum_{i,k=1}^{n} a_{ik} = 1/\text{n}\sum_{k=1}^{n} a_{kk}$$

Over all accuracy= (12766+59897+17600+30336)/127898=94.2%

Kappa Statistics can be computed as:

$$\text{K} = \text{N} \sum_{i=1}^{n} a_{ii} - \sum_{i=1}^{n}(a_{i+} * \dot{a}_{+i}) / \text{N}^2 - \sum_{i=1}^{n}(a_{i+} * \dot{a}_{+i})$$

Where

n=no. of the rows in the matrix

$\dot{a}_{ii}$=the no. of observations in row *i* and column *i* (on the major diagonal)

$\dot{a}_{i+}$=total of observations in row *i*

$\dot{a}_{+i}$= total of observations in column *i*

N=total no. of observations included in matrix

Therefore

Kappa Statistics:

$$\text{K}= \frac{127898(12766+59897+17600+30336)-((13717*17934)+(65065*59897)+(17600*18780)+(31516*31287))}{127898*127898-((13717*17934)+(65065*59897)+(17600*18780)+(31516*31287))}$$

=0.91

An overall accuracy of 0.942 and a Kappa Index of Agreement (KIA) of 0.91 are fairly reasonable and good accuracy levels. However, it is felt that there is still much misclassification that can be improved upon. It is hoped that this can be improved by exploiting some class related features and topological relationships.

Histogram for this classification is given in figure 1.

Statistics of the classified image are given in table 3.

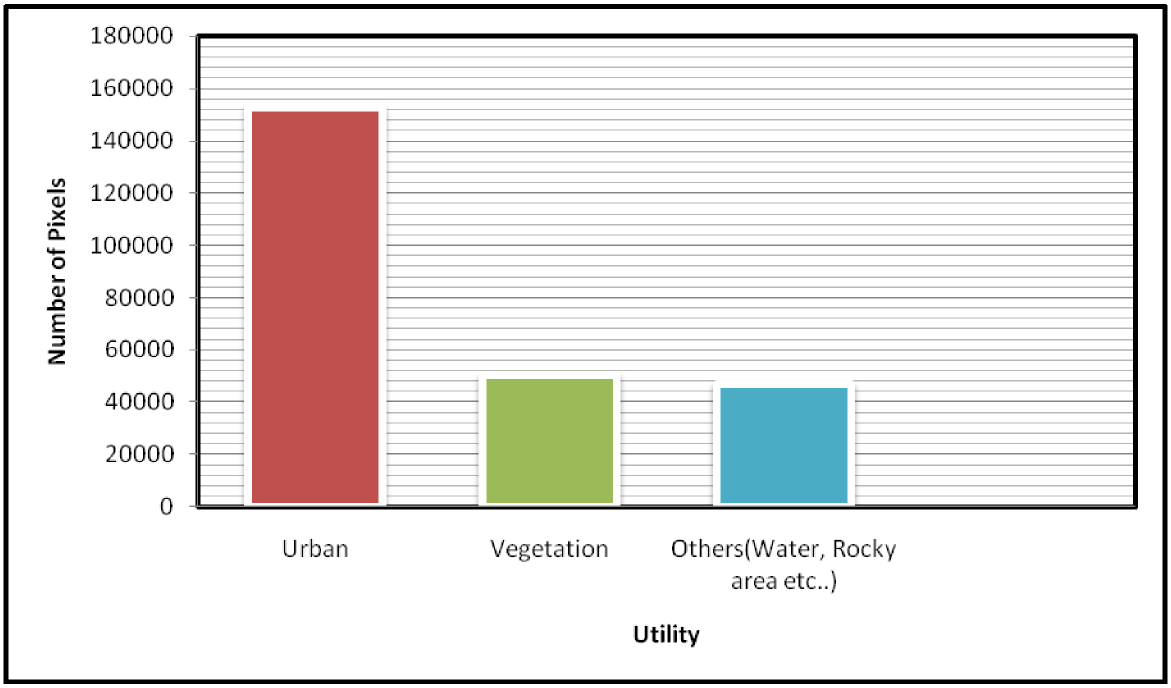


Figure 1: Histogram of the classified image

Table 3: Statistics of classification result

Land cover lasses	**Pixel number**	**Pixel no. P(%)**	**Area(Sq.Km)**
1)Urban	152746	10.54	34.6
2)Vegetation(Forestry)	50326	3.47	11.4
3)Others(Water, Rocky area etc..)	46795	3.23	10.6

From the Histogram of this classification it is clear that out of the 58 sq.kms of the study area the urban area covers 34.6 sq.km which includes residential, commercial, industrial, traffic and transportation, public utility etc., the vegetation (trees, plants, shrubs etc.,) covers 11.4 sq.km and water, rocky area etc., covers 10.6 sq.km.

3. CONCLUSIONS, RECOMMENDATIONS AND PROPOSALS

3.1 PLANNING EFFORTS

The way with which the city is growing and developing due to the migration of population from rural areas for employment and other opportunities, it has been proposed that the ultimate land use structure of the Vijayawada urban area in the coming 20 years should be around 130 sq.km. The residential area is proposed to cover about 48% followed by transport and recreation uses. The land use pattern for the coming 20 years should definitely be far more balanced compared to the prevailing situation if the authorities concerned look in to the following recommendations and proposals.

3.2 RECOMMENDATIONS AND PROPOSALS

- The proposals aim at municipal performance improvement of environmental infrastructure and aims at socio-economic development.
- The proposals for municipal reforms are aimed at enhancing the efficiency, effectiveness and service delivery with accountability.
- The reform proposals should include privatization of advertisement tax collection, revenue improvement, town development, operation and maintenance of critical infrastructure investment.
- The environmental infrastructure proposals aim at improvement of infrastructure in the prioritized poor settlements as per poverty and infrastructure deficiency matrices and linked infrastructure for poor settlements.
- These include rehabilitation of existing infrastructure provision of water supply, roads, drains, sanitation and street lighting based on community prioritization and construction of drains to improve the living environment.
- The social development proposals aim at addressing the socio-economic needs identified and prioritized through participatory micro planning process.
- These proposals cover areas of health, education, livelihood, vulnerability and strengthening of SHGs (Self help groups), with focus on gender issues.
- This leads to the reduction of poverty and improvement in living conditions of the people in the poor settlements.

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