"Comparative Analysis of Different Supervised Classification Techniques for Spatial Land Use/Land Cover Pattern Mapping Using RS and GIS"

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Abstract—The present study highlights the advantages of Remote Sensing (RS) and Geographic Information System (GIS) techniques for analyzing the land use/land cover mapping for Aurangabad region of Maharashtra, India. Single date, cloud free IRS-Resourcesat-1 LISS-III data was used for further classification on training set for supervised classification. Some image enhancement techniques were also performed to improve the satellite imagery for better visual interpretation. ENVI 4.4 image analysis tool and Arc GIS10 software were used for data processing and analysis. Maximum Likelihood, mahalanobis distance, minimum distance and parallelepiped classifiers were performed for LULC classification in this study. The main objective of this study is to develop land use/land cover map for Aurangabad region to predict the possible applications of LULC. Level-II of Anderson classification was also performed for LULC mapping analysis. It is observed that maximum area is covered by barren land, agricultural area (with crops and without crops), hilly area, built-up area and water bodies' etc respectively. The result of the classifications suggests that, each used and covered type were best classified by the Maximum likelihood classification technique.

Index Terms—Image Enhancement, Land use/Land cover, Maximum Likelihood Classification, Remote Sensing and GIS, Supervised Classification.

1 Introduction

From the past two decades, the economic development and population growth have triggered a rapid change to the Earth's land cover and the indication shows that the pace of these changes is going to increase in the coming future. The rapid changes are superimposed on long-term dynamics that are associated with the climate variation. Land cover change can affect the ability of the land to sustain human activities through the provision of multiple ecosystem services and because the resultant economic causes the feedbacks affecting climate and other facets of global change. To study the human-induced changes in the land cover change at spatial level details there is a need of systematic assessment of Earth's land cover which must be repeated at certain frequency that permits the monitoring of both long-term trends as well as inter-annual variability [1], [2], [3]. Land cover is the collection of biotic and abiotic elements on the Earth's surface which is one of the most vital properties of the earth system. However land cover may also be defined as, the physical material on the Earth surface which is covered by different parts of the nature or also the man made parts on the Earth surface i.e. soil, rocks, water bodies, vegetation, built-up areas, trees, etc.

Land use means those areas which are used by humans for their need [2], [4]. Hence, Information on land use/land cover is very much helpful in planning and management of different patterns on the earth surface to many national and global applications including watershed management and agricultural productivity. Thus, this information is required to monitor land cover changes for projecting future land development using remote sensing and GIS technology [5], [6]. The Anderson classification of land use and land cover includes various classes such as built-up area, agricultural area, water, forest, barren, etc. On which level has to be used is depends on at what scale is being used [7]. In the present work, we have performed level-II of Anderson classification for LULC mapping analysis.

2 Study Area

Aurangabad district is located in central part of Maharashtra is establish to be tactically as the gateway to the Marathwada region. It is the districts headquarter and located in central part of the state. The population of Aurangabad district is near about 37 Lakhs with the geographical area is 10,100 sq.km i.e. 3.27% of the total area of the Maharashtra. Among these total area of the district 141.1 sq.km is covered by urban area (1.4%) with population of 37.5%, whereas remaining 99,587 sq.km (98.6%) is rural area. The Aurangabad district includes of 9 Talukas and 1344 villages with gender ratio of the district is 917 [8]. Among that the metropolitan city area is around 300km2 (100 sq mi). The study area Aurangabad is the capital metro city of Maharashtra State. The coordinates for Aurangabad are N 19° 53' 47" – E 75° 23' 54". The

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city is surrounded by hills on all directions. The city is a tourist heart called as city of Gates as well as fastest growing city in the world, surrounded with many historical monuments, including the Ajanta Caves and Ellora Caves, which are UNESCO World Heritage Sites, as well as Bibi Ka Maqbara [9]. The bellowed Figure 1 shows the study area-Aurangabad region of Aurangabad district [10], [11], [12].

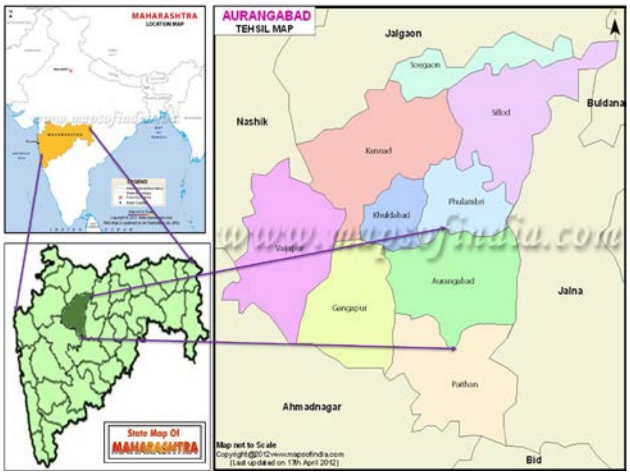

Fig. 1. Study area-Aurangabad Region, Maharashtra State, India

3 Materials And Methods

The data required for the study is obtained from NRSC Balanagar, Hyderabad. The Survey of India Toposheet E43D05 at 1:50,000 scale is used to prepare base map. The metadata tile number is E43D05 and the dataset name is L3_SAT_8B_v1_75.25E19.75_E43D05_23oct08. The geometrically corrected IRS-Resourcesat-1 LISS-III satellite single date multispectral imagery was used for the preparation of Land use Land cover map. This data is received from Linear Imaging and Self Scanning Sensor (LISS) which operates in three spectral bands in VNIR and one band in SWIR with 23.5 meter spatial resolution and a swath of 141 km. The IRS-Resourscesat-1 LISS-III satellite imagery has four bands i.e. Band 2 - Green, band 3 - Red, band 4 - NIR and band 5 - SWIR. Figure 2 shows the Original Satellite Image and Figure 3 shows the methodology used in experimentation.

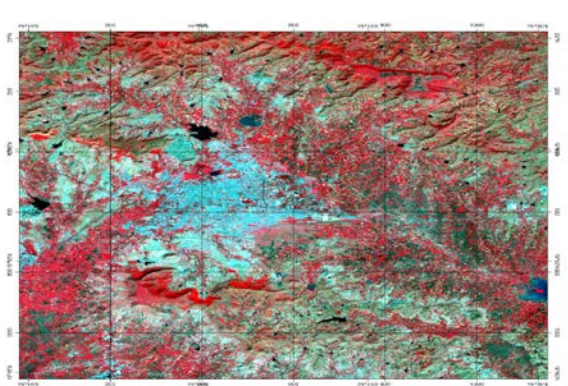

Fig. 2. Original Satellite Imagery

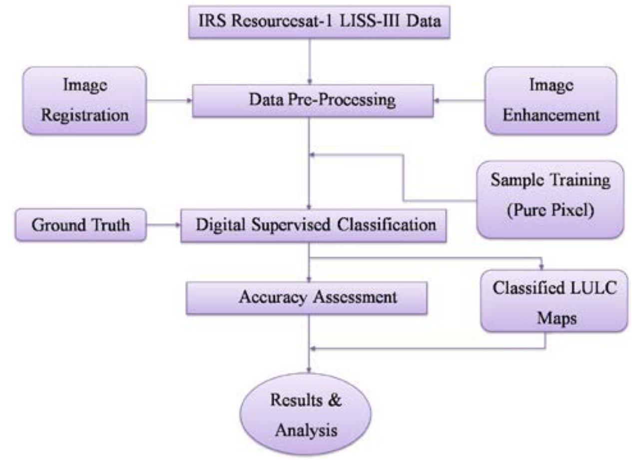

Fig. 3. Workflow Diagram for proposed Methodology

The Basic Statistics of original satellite image is shown in Table 1, 2, 3 and 4 respectively.

TABLE 1
BASIC STATISTICS OF ORIGINAL SATELLITE IMAGE

Basic Stats	Min	Max	Mean	Stdev	Num	Eigen value
Band 1	33	255	58.159390	8.135796	1	208.651394
Band 2	16	255	45.894443	10.905736	2	149.687512
Band 3	6	255	71.028343	11.946399	3	15.010884
Band 4	6	237	39.988043	6.948197	4	2.770359

TABLE 2
COVARIANCE OF ORIGINAL SATELLITE IMAGE

Covariance	Band 1	Band 2	Band 3	Band 4
Band 1	66.191173	83.781033	3.838577	36.714652
Band 2	83.781033	118.935089	-7.863459	54.344766
Band 3	3.838577	-7.863459	142.716439	32.824819
Band 4	36.714652	54.344766	32.824819	48.277448

TABLE 3
CORRELATION OF ORIGINAL SATELLITE IMAGE

Correlation	Band 1	Band 2	Band 3	Band 4
Band 1	1	0.944258	0.039494	0.649482
Band 2	0.944258	1	-0.060356	0.717184
Band 3	0.039494	-0.060356	1	0.395451
Band 4	0.649482	0.717184	0.395451	1

TABLE 4
EIGENVECTOR OF ORIGINAL SATELLITE IMAGE

Eigenvector	Band 1	Band 2	Band 3	Band 4
Band 1	0.536030	0.729921	0.142949	0.399316
Band 2	0.093497	0.209245	-0.959374	-0.164551
Band 3	-0.493498	-0.058579	-0.205478	0.843094
Band 4	0.678520	-0.648075	-0.130179	0.320410

3.1 Pre-Processing

Pre-processing of remote sensing data includes geometric and radiometric corrections as well as image enhancement. These operations aim to correct the degraded image data to create a more faithful representation of the original scene and to improve the satellite imagery for better classification.

3.1.1 Geometric and Radiometric Corrections

Geometric correction is repositioning pixel's geographical position using coordinate without changing the radiance reflectance and recalculation of radian value of the pixel through resample. Whereas radiometric correction of RS image basically involves the processing of digital images to improve the fidelity of the brightness value magnitudes. In this step, the geometric and radiometric corrections are carried out. The geometric correction executed after the radiometric correction. Hence the radiometric as well as geometric corrections will be very much useful to clear the influences caused by the changing correction orders and it improves the accuracy of the product. Radiometric calibration as well as atmospheric correction recalculation of the radiance of pixel is performed in radiometric correction to avoid radiometric errors or distortions. Geometric correction is to remove geometric distortion using registration, local incident angle corrections using toposheet and require the knowledge of the geodetic co-ordinates of some relating points on the ground [13], [14], [15], [16]. For this study here we have used orthocorrected (geometric as well as radiometric corrected) satellite imagery from Bhuvan website prepared by NRSC, Hyderabad.

3.1.2 Image Enhancement

In order to improve satellite imagery for better visual interpretation, we required some image enhancement techniques. Grey level stretching and spatial filtering are applied for enhancing the edges and textures of the image. These techniques are applied on Green, Red and NIR Bands respectively.

3.1.2.1 Linear Contrast Stretch

It is the simplest type of satellite image enhancement. This uses minimum and maximum brightness values of the image to perform a linear contrast stretch (no clipping). This is particularly useful for displaying images with only a few data values, where clipping might saturate all of the values. To cover the full range of values from 0 to 255 linear stretches equivalently expands small range. This enhances the contrast in the image with light toned areas appearing lighter and dark areas appearing darker, making visual interpretation much easier [17], [18].

3.1.2.2 Median Filter

The median filter specially uses moving windows or kernels of 3x3 and 5x5 sizes for replacing the center pixel value with the median value in the kernel. The median filter is usually used to remove the salt and pepper type noise or speckle [17], [18].

3.1.2.3 Sharpen Filter

The sharpening filter is specially used to highlight the fine detail as well as the linear textures in an image. This filter executes the high pass filter on the data in the display group. For this the high-pass filter implements a low-pass filter to an image then subtracts the result from the original image. The sharpening filters with higher kernel center values have a larger amount of original data added back to the filtered image [17], [18].

For this particular study we applied sharpen filter on linear stretching and median filter for highlighting the texture and smoothing the image for better visual interpretation and we got the better enhanced image for further classification.

The following Figure 4 and 5 shows the flowchart of image enhancement as a pre-processing and enhanced image using linear stretching, median and sharpening filters respectively.

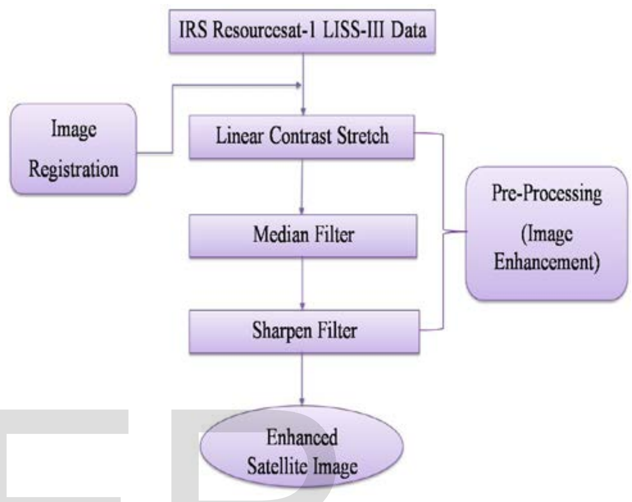

Fig. 4. Flowchart of Image Enhancement

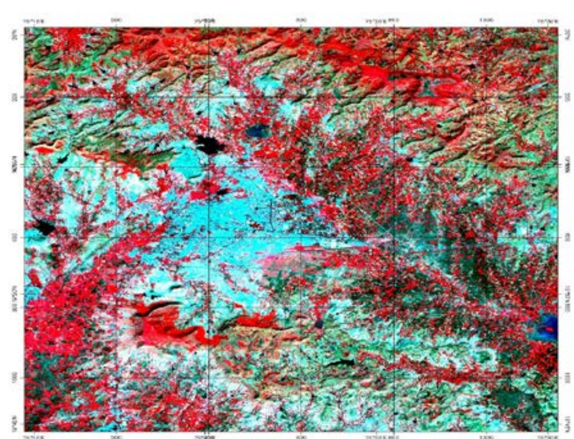

Fig. 5. Enhanced satellite image using sharpen filter on linear and median filter

The Basic Statistics of enhanced satellite image is shown in Table 5, 6, 7 and 8 respectively.

TABLE 5
BASIC STATISTICS OF ENHANCED SATELLITE IMAGE

Basic Stats	Min	Max	Mean	Stdev	Num	Eigenvalue
Band 1	0	255	138.284690	78.193232	1	12560.78872
Band 2	0	255	120.975708	80.048373	2	6004.529529
Band 3	0	255	113.958503	79.071574	3	208.919134

TABLE 6
COVARIANCE OF ENHANCED SATELLITE IMAGE

Covariance	Band 1	Band 2	Band 3
Band 1	6114.181531	371.472863	991.066560
Band 2	371.472863	6407.742043	6086.757077
Band 3	991.066560	6086.757077	6252.313807

TABLE 7
CORRELATION OF ENHANCED SATELLITE IMAGE

Correlation	Band 1	Band 2	Band 3
Band 1	1	0.059348	0.160293
Band 2	0.059348	1	0.961641
Band 3	0.160293	0.961641	1

TABLE 8
EIGENVECTOR OF ENHANCED SATELLITE IMAGE

Eigenvector	Band 1	Band 2	Band 3
Band 1	0.147745	0.700043	0.698650
Band 2	0.986102	-0.158538	-0.049679
Band 3	-0.075985	-0.696280	0.713737

3.2 Digital Classification

In this study, four different classification algorithms were implemented for land use land cover pattern analysis. In that, supervised classification techniques such as Maximum Likelihood, Mahalanobis distance, Minimum distance and Parallelepiped classification which is the main pixels based classification algorithms were implemented.

3.2.1 Supervised Classification

Supervised classification is based on the training set, which creates necessity to have knowledge of the land cover and spectral reflectance of the interested region [19].

3.2.1.1 Maximum Likelihood Classifier

It is based on statistical decision criteria for classification of overlapping signatures and pixels are assigned to the class of highest probability. Gaussian maximum likelihood classifier uses variance and co-variance to classify an unknown pixel of spectral response pattern. This classification is depends on probability density function related with a specific signature. Pixels are assigned to most likely class based on a comparison of the posterior probability that it belongs to each of the signatures being considered [19]. The overall accuracy of 74.1176% with Kappa Coefficient of 0.7038 is achieved.

3.2.1.2 Mahalanobis Distance Classifier

This classifier based on the correlations between variables by which different patterns can be identified and analyzed. It measures the similarity of an unknown sample set to a known one. Its approach is different from Euclidian distance. It takes into account the correlations of the data set and is scale-invariant [19]. The overall accuracy of 68.2353 % with Kappa Coefficient of 0.6347 is achieved.

3.2.1.3 Minimum Distance Classifier

It is used to classify unknown image data; it also minimizes the distance between image data and class in multi-feature space. The distance is defined as an index of similarity so that the minimum distance is identical to the maximum similarity. It uses mean vector in each class signature, while standard deviation and covariance matrix are ignored [19]. Overall accuracy of 62.9412 % with Kappa Coefficient of 0.5737 is obtained by this classifier.

3.2.1.4 Parallelepiped Classifier

It is based on geometrical shape whose opposite sides are straight and parallel. It uses the class limits and stores of each class signature to determine if a weather pixel falls within the class or not. The class limits specify the dimensions (in standard deviation units) of each side of a parallelepiped surrounding the mean of the class in feature space. It is normally used when classification speed is required except pure accuracy and large number of pixels classified as an overlap [19]. Using this classifier we observed 51.7647 % overall accuracy with Kappa Coefficient of 0.4505.

4 ACCURACY ASSESSMENT

Accurately assessment is an important part of land use land cover classification [20]. The classification accuracy can be estimated through confusion matrix or error matrix in terms of producer's accuracy, user's accuracy and overall accuracy with kappa coefficient, to generate such matrix ground truth data is mandatory [2], [20], [21]. An error matrix can be used to map classified labels against actual observed ground truth for a sample of cases at specified location. The need for accuracy assessment initially arose as part of algorithm development, and it was extended into an important tool for users of land cover products.

5 RESULTS AND DISSCUSSION

The results of this study shows that, classification of remotely sensed imagery gives valuable information in land use land cover activities in the form of different objects on the earth surface. Land use land cover analysis was done by maximum likelihood, mahalanobis, minimum distance and parallelepiped supervised classification algorithms. Supervised classification was done using maximum likelihood, mahalanobis distance, minimum distance and parallelepiped classifiers to classify the data in to eight classes (Agriculture crop area, agriculture area without crop, built-up area, barren land, Hills with vegetation, hills without vegetation, hill with rocks and water bodies) as illustrated in Figure 6, 7, 8 and 9 respectively.

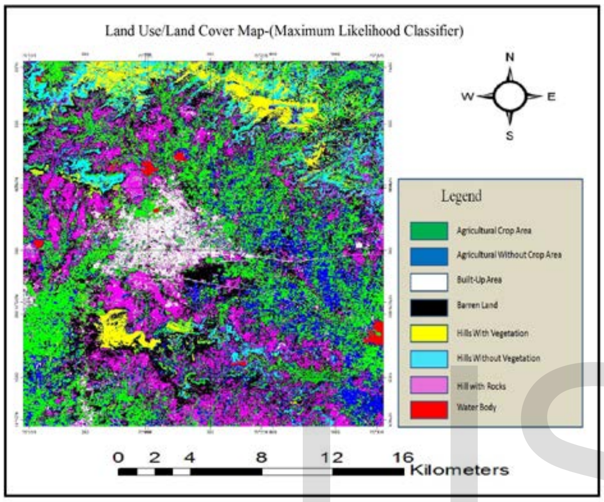

Fig. 6. Land Use/Land Cover Map using Maximum Likelihood classifier

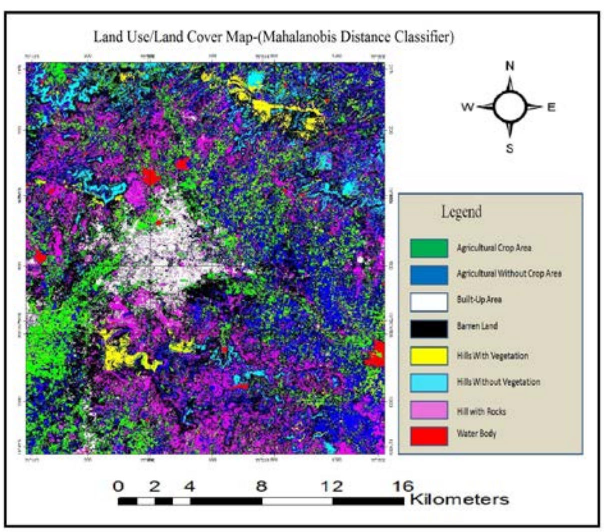

Fig. 7. Land Use/Land Cover Map using Mahalanobis Distance classifier

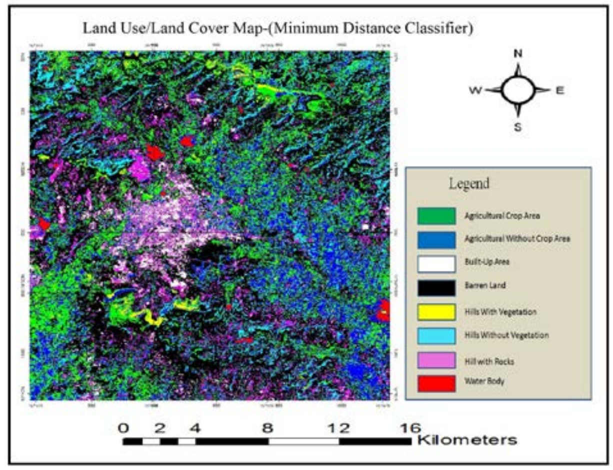

Fig. 8. Land Use/Land Cover Map using Minimum Distance classifier

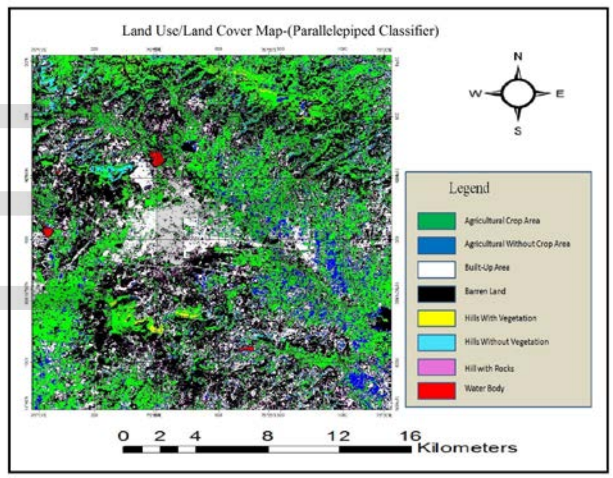

Fig. 9. Land Use/Land Cover Map using Parallelepiped classifier

The composition of land use land cover classes are listed in Table 9, which describes the comparison of four supervised classifiers. Result of Agricultural crop area shows highest area using parallelepiped classifier and lowest area using mahalanobis classifier. Agriculture without crops shows highest area using mahalanobis classifier, whereas parallelepiped classifier having lowest value. Built-up area shows highest area using parallelepiped classifier, whereas minimum distance having lowest one. Minimum distance classifier shows highest area of barren land and lowest area using parallelepiped classifier. Hilly area was highest classified by maximum likelihood classifier, where as lowest by parallelepiped classifier. Very less area was covered by water bodies within the study area. Among the four classifiers unclassified area was classified by only parallelepiped classifier.

TABLE 9
LAND USE/LAND COVER DISTRIBUTION IN AURANGABAD REGION USING DIFFERENT CLASSIFIER

Classes	Classifiers							
	Maximum Likelihood Classifier		Mahalanobis Classifier		Minimum Distance Classifier		Parallelepiped Classifier	
	Area (in Hectares)	Area (%)	Area (in Hectares)	Area (%)	Area (in Hectares)	Area (%)	Area (in Hectares)	Area (%)
Agriculture Crop Area	17500.5736	22.431	9733.9264	12.476	10551.5670	13.524	21141.7507	27.098
Agriculture Area without Crops	9294.9404	11.913	15249.7730	19.546	7741.0006	9.922	6039.1085	7.740
Built-up Area	5254.2157	6.734	4651.1969	5.962	2995.4922	3.839	14930.8039	19.137
Barren Land	20443.9509	26.203	28082.3062	35.994	37779.0831	48.422	19724.8473	25.282
Hills with vegetation	5701.3593	7.308	4489.9811	5.755	1225.5220	1.571	684.2429	0.877
Hills without vegetaion	6501.9217	8.334	3530.5503	4.525	11015.8475	14.119	1267.8947	1.625
Hill with Rocks	12756.9432	16.351	11486.9944	14.723	6010.2340	7.703	1098.0517	1.407
Water Bodies	566.3388	0.726	795.5153	1.020	701.5559	0.899	153.1756	0.196
Unclassified	0.00	0.00	0.00	0.00	0.00	0.00	12980.4269	16.637
Total Area	**78020.24**	**100.00**	**78020.24**	**100.00**	**78020.30**	**100.00**	**78020.3022**	**100.00**

In this work we have used confusion matrix or error matrix for maximum likelihood, mahalanobis distance, minimum distance, and parallelepiped supervised classifiers for accuracy assessment in the terms of producer's accuracy, user's accuracy and overall accuracy with kappa coefficient listed in Table 10, 11, 12 and 13 respectively. 170 random points were selected to generate accuracy assessment report of each classification. These points were representative of each different class and the number of points was selected considering the size of the study area and available ground truth data.

TABLE 10
ERROR MATRIX FOR MAXIMUM LIKELIHOOD CLASSIFIER

Classes	Ground Truth (Pixels)								
	Agri Crop1	Agri Fallow1	Built-up Area1	Barren Land1	Hillswit hVege1	Hillswith outVeg1	Hill-withRoc ks1	Water Body1	Total
Unclassified	0	0	0	0	0	0	0	0	0
Agriculture Crop Area	**22**	2	0	0	1	0	0	0	25
Agriculture without crops	1	**11**	0	0	0	0	0	2	14
Built up Area	0	0	**27**	4	0	0	3	0	34
Barren Land	1	3	0	**5**	0	1	0	0	10
Hills with vegetation	1	0	0	0	**24**	0	0	0	25
Hills without vegetation	1	0	0	0	0	**13**	0	0	14
Hill with Rocks	0	2	2	17	0	3	**8**	0	32
Water body	0	0	0	0	0	0	0	**16**	16
Total	**26**	**18**	**29**	**26**	**25**	**17**	**11**	**18**	**170**

TABLE 11
ERROR MATRIX FOR MAHALANOBIS DISTANCE CLASSIFIER

Classes	Ground Truth (Pixels)								
	Agri Crop1	Agri Fallow1	Built-up Area1	Barren Land1	Hills with Vege1	Hillswith outVeg1	Hill with Rocks1	Water Body1	Total
Unclassified	0	0	0	0	0	0	0	0	0
Agriculture Crop Area	**14**	1	0	0	2	0	0	0	25
Agriculture without crops	2	**8**	0	0	0	2	1	0	14
Built up Area	0	0	**23**	1	0	0	4	0	34
Barren Land	3	8	2	**13**	0	3	0	0	10
Hills with vegetation	7	0	0	0	**23**	0	0	0	25
Hills without vegetation	0	0	0	0	0	**11**	0	0	14
Hill with Rocks	0	1	4	12	0	1	**6**	0	32
Water body	0	0	0	0	0	0	0	**18**	16
Total	**26**	**18**	**29**	**26**	**25**	**17**	**11**	**18**	**170**

TABLE 12
ERROR MATRIX FOR MINIMUM DISTANCE CLASSIFIER

Classes	Ground Truth (Pixels)								
	Agri Crop1	Agri Fallow1	Built-up Area1	Barren Land1	HillsWith Vege1	Hillswith-outVeg1	Hill-withRocks1	Water Body1	Total
Unclassified	0	0	0	0	0	0	0	0	0
Agriculture Crop Area	**13**	1	0	0	9	0	0	0	23
Agriculture without crops	2	**7**	1	0	0	0	0	0	10
Built up Area	0	0	**16**	7	0	0	3	0	26
Barren Land	3	3	1	**18**	0	5	1	0	31
Hills with vegetation	7	0	0	0	**16**	0	0	0	23
Hills without vegetation	1	5	0	0	0	**12**	0	0	18
Hill with Rocks	0	2	11	1	0	0	**7**	0	21
Water body	0	0	0	0	0	0	0	**18**	18
Total	**26**	**18**	**29**	**26**	**25**	**17**	**11**	**18**	**170**

TABLE 13
ERROR MATRIX FOR PARALLELEPIPED CLASSIFIER

Classes	Ground Truth (Pixels)								
	Agri Crop1	Agri Fallow1	Built-up Area1	Barren Land1	Hillswith Vege1	Hillswith outVeg1	Hill-withRocks1	Water Body1	Total
Unclassified	0	1	0	17	1	1	2	10	32
Agriculture Crop Area	**23**	3	0	0	15	0	0	0	41

Agriculture without crops	1	**6**	0	0	0	0	0	0	7
Built up Area	0	5	**29**	5	0	4	9	0	52
Barren Land	1	3	0	**4**	0	3	0	0	11
Hills with vegetation	1	0	0	0	**9**	0	0	0	10
Hills without vegetation	0	0	0	0	0	**9**	0	0	9
Hill with Rocks	0	0	0	0	0	0	**0**	0	0
Water body	0	0	0	0	0	0	0	**8**	8
Total	**26**	**18**	**29**	**26**	**25**	**17**	**11**	**18**	**170**

The producer's accuracy, user's accuracy corresponding to the various classes and overall accuracy results obtained are summarized in Table 14.

TABLE 14
ACCURACY ASSESSMENT OF FOUR CLASSIFIERS (IN %)

Classes	**Maximum Likelihood Classifier**			**Mahalanobis Classifier**			**Minimum Distance Classifier**			**Parallelepiped Classifier**		
	PA	**UA**	**OA**	**PA**	**UA**	**OA**	**PA**	**UA**	**OA**	**PA**	**UA**	**OA**
ACA	84.62	88.00		53.85	82.35		50.00	56.52		88.46	56.10	
AWC	61.11	78.57		44.44	61.54		38.89	70.00		33.33	85.71	
BA	93.10	79.41		79.31	82.14		55.17	61.54		100.00	55.77	
BL	19.23	50.00	74.11	50.00	44.83	68.23	69.23	58.06	62.94	15.38	36.36	51.76
HWV	96.00	96.00		92.00	76.67		64.00	69.57		36.00	90.00	
HWV	76.47	92.86		64.71	100.00		70.59	66.67		52.94	100.00	
HWR	72.73	25.00		54.55	25.00		63.64	33.33		0.00	0.00	
WB	88.89	100.00		88.89	100.00		100.00	100.00		44.44	100.00	

ACA- Agriculture Crop Area, **AWC**- Agriculture Without Crops, **BA**- Built-Up Area, **BL**- Barren Land, **HWV**- Hills With Vegetation, **HWV**- Hills Without Vegetation, **HWR**- Hill With Rocks, **WB**- Water Body, **PA**- Producer's Accuracy, **UA**- User's Accuracy, **OA**- Overall Accuracy.

According to accuracy assessment results, for the maximum likelihood classifier overall accuracy was 74.1176% and Kappa Coefficient was 0.7038. Mahalanobis distance classifier overall accuracy was 68.2353% and Kappa Coefficient was 0.6347. For minimum distance classifier overall accuracy was 62.9412% and Kappa Coefficient was 0.5737 and for parallelepiped classifier overall accuracy was 51.7647% and Kappa Coefficient was 0.4505.

6 CONCLUSION

GIS and Remote Sensing techniques is a powerful technique for mapping and evaluating the Land Use and Land Cover study in any environment. The land cover classifications were performed by using multi-spectral IRS-Resourcesat-1 LISS-III single date reflectance products. In this study, the efficiency of satellite imagery in land use/ land cover mapping analysis is focused. Various techniques were used for land use/land cover mapping based on different statistical parameters. The results indicate that, acceptable classification performance of land use/land cover can be obtained by using pixel based classification techniques. For this particular study supervised classification approaches were tried to extract the land use/land cover patterns in the Aurangabad region. The Maximum likelihood classifier resulted superior as compared to other classifiers. It is concluded that maximum likelihood is a more effective technique for remote sensing image classification than others.

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