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Roads Extraction Using Road Extraction Index-Principal Component (REI-PC) and Contrast Enhancement of Satellite Imagery

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Abstract-Road feature extraction is a challenging task. In this work, a new road index is developed for automatic identification of road pixels. Area of interest is extracted with desired shape. Here, Sri Kalahasti town and its neighboring area (as an example) are extracted from Chittoor district of AP state. Road indices are used to detect road pixels from Landsat-8 image, which has high spectral resolution. This image is multi-spectral image comprising of eleven bands. Interactive supervised classification is used for segmentation purpose. The image is classified into three categories i.e. Roads, urban, and vegetation. Built-up Area Index-Principal Component (BAI-PC) and Road Extraction Index-Principal Component (REI-PC) are applied on Landsat-8 imagery. Finally accuracy assessment is carried out by confusion or error matrix. Quantitative parameters such as Overall Accuracy (OA), Kappa Coefficient (KC), Completeness, Correctness, Quality, and Redundancy are calculated for multi-spectral satellite imagery. The new algorithm developed reduces misclassification of road pixels with urban pixels. The algorithm gave good results in terms of quantitative performance metrics.

Keywords-Error matrix, accuracy assessment, Road Extraction Index-Principal Component, Built-up Area Index-Principal Component Analysis (PCA) .

1. INTRODUCTION

Roads play a vital role in man-made objects [1]-[3]. Roads extraction has many important applications such as post hazard rescue, transportation, urban design, and emergency services [4] - [6]. Urban extraction is done with very high resolution images, obtained from IKONOS, World view, Geoeye, and Quick bird satellite sensors [7], [8].

BAI based on built-up area extraction in SPOT satellite imagery was proposed in [9]. Previously they concentrated on Landsat-TM imagery. Studies from previously developed results reveals, fully automated road indices for roads extraction [10] - [13]. Accurate and timely road extraction information is done by high resolution imagery [14] -[18]. Previously data is extracted by IKONOS and Quick Bird satellites [19] - [21]. Road extraction with REI was proposed in paper [22]. We propose a new novel road index i.e. REI-PC. It gave better results in road feature extraction and qualitative performance metrics.

2. MATERIALS AND METHODS

Sri Kalahasti town and its neighboring area from Chittoor district in Andhra Pradesh is used for roads analysis. To analyze Sri Kalahasti, ArcGIS 10.3 tool is used. The total image size is 7631×7801.Preprocessing is applied by nearest neighbor interpolation algorithm. Area of Interest (AOI) is extracted from 143/50 (row/path). Here, AOI is Sri Kalahasti town and its neighboring area, which is extracted from Chittoor district [25]. Geo-processing clip is applied for shape file. Then Raster clip is applied for satellite image and shape file, to extract desired area. Then clip to shape is applied to extract, Sri Kalahasti town and its neighboring area from the total raster. BAI and REI are calculated for, Sri Kalahasti town and its neighboring area and Contrast Enhancement is performed by multiplying road indices with scaling factor 2. Then principal component (PC) is applied to road indices (RI).

The merits of principal component analysis are data reduction and noise reduction. The resultant images are BAI-PC and REI-PC after application of PCA. Segmentation of satellite data is done by classification techniques. Then Interactive supervised classification is performed. All evaluation performance metrics are calculated with the help of confusion matrix.

For validating satellite data 50 ground truth points (GTP) or tie points in each class are selected. Total 150 tie points are selected in all the three land covers. Shape file is created for these two classes with 150tie points. Then shape file is converted into raster. This resultant raster is combined with classified image. Now pivot table is generated which gives confusion matrix. While creating shape file the input image and shape file should be in same coordinate system. Otherwise pixels are misclassified. Quantitative performance metrics such as OA, KC, Completeness, Correctness, Quality, and Redundancy are calculated. The algorithm for road extraction and enhancement is shown in Fig. 1.

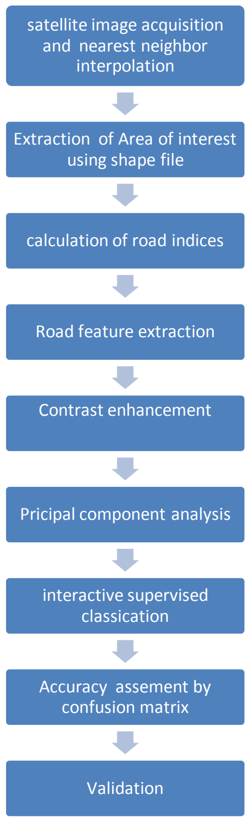

Fig. 1: Algorithm for road feature extraction

2.1 Data set

The data set is downloaded from United States Geological Survey (USGS) earth explorer. These images are collected from satellite LANDSAT-8 Operational Land Imager (OLI). Table 1 describes Landsat-8 OLI characteristics. Table 2 presents various bands of Landsat-8 0LI. In this paper, extraction of roads is main scenario. So band 2, band 4, band 5, and band 7 are selected for road feature extraction. They gave better results compared to other spectral bands.

Table 1: Landsat-8 OLI main characteristics

Acquired images dates	19/03/2018
Path/Row	143/50
Datum	WGS 84
Projection	UTM
Spatial Resolution	30m
File Format of Acquired images	Geo-Tiff
Total number of bands	11
Type of Sensor	OLI
Radiometric Resolution	16 bits
Temporal Resolution	16 days
Swath	190 km

Table 2: Landsat-8 bands description

Bands	Wavelength (μm)	Resolution (m)
Band 1	0.43-0.45	30
Band 2	0.45-0.51	30
Band 3	0.53-0.59	30
Band 4	0.64-0.67	30
Band 5	0.85-0.88	30
Band 6	1.57-1.65	30
Band 7	2.11-2.29	30
Band 8	0.50-0.68	15
Band 9	1.36-1.38	30
Band 10	10.6-11.19	100
Band 11	11.5-12.51	100

Here band 1 is coastal aerosol , band 2 is Blue, band 3 is Green, band 4 is Red, band 5 is Infra Red, band 6 is Short Wave Infra Red (SWIR1) , band 7 is SWIR2, band 8 is panchromatic , band 9 is Cirrus, band 10 is Thermal Infra red (TIRS1), and band 11 is TIRS2. Here, we have concentrated on blue, NIR, and NIR2 bands for road feature extraction [22]. BAI and REI are calculated as:

$$BAI_{L8}=B_{L8}-NIR_{L8}/B_{L8}+NIR_{L8} \quad (1)$$
$$REI_{L8}=NIR2_{L8}-B_{L8}/(NIR2_{L8}+B_{L8}*(NIR2_{L8}))(2)$$

In 3×3confusion matrix, there are nine elements as shown in Table 3. Confusion matrix quality parameters [22] are calculated as:

Table 3:3×3confusion matrix

Landcover	A	B	C
A	X_{AA}	X_{AB}	X_{AC}
B	X_{BA}	X_{BB}	X_{BC}
C	X_{CA}	X_{CB}	X_{CC}

$$OA=X_{AA}+X_{BB}+X_{CC}/(X_{AA}+X_{AB}+X_{AC}+X_{BA}+X_{BB}+X_{BC}+X_{CA}+X_{CB}+X_{CC}) \quad (3)$$

$$KC=N\times\sum_{j=1}^{n} x_{jj}-\sum_{j=1}^{n} x_{j+}*x_{+j}/(N^2-\sum_{j=1}^{n} x_{j+}*x_{+j}) \quad (4)$$

*N*is the total number of pixels in confusion matrix

Σx_{jj} is the sum of correctly classified pixels
$\Sigma x_{j+}$is the sum of row total
Σx_{+j} is the sum of column total

X_{AA}, X_{AB}, X_{AC} , X_{BA} , X_{BB} , $X_{BC,}$ X_{CA} , X_{CB}, and X_{CC} are confusion matrix values. TP values are diagonal elements. All other values are false in the matrix. Quality parameters [23] calculations for land cover A is shown below.

$$\text{Completeness}=X_{AA}/(X_{AA}+X_{AB}+X_{AC}) \quad (5)$$
$$\text{Correctness}=X_{AA}/(X_{AA}+X_{BA}+X_{CA}) \quad (6)$$
$$\text{Quality}=X_{AA}/(X_{AA}+X_{BA}+X_{CA+}X_{AB}+X_{AC}) \quad (7)$$
$$\text{Redundancy}= (2^*X_{AA}+X_{BA}+X_{CA})/X_{AA} \quad (8)$$

OA deals with the overall accuracy of pixels in Roads and Non Roads. KC is a statistical measure which determines the classification of land cover in satellite data.

PCA [24] is calculated with Eigen value decomposition of data covariance matrix or singular value decomposition of data matrix.

Eigen values is calculated by
$\text{Det (cov-}\lambda I)=0$
Cov is the covariance matrix, *I* is the identity matrix, λisEigen value matrix.
Eigen vectors can be calculated by
$\text{Det(cov-}\lambda_k I)V_k=0$
λ_k is the Eigen value matrix , v_k is the Eigen vector matrix.

PCA is mainly used to reduce data set dimensions. It eliminates noise in satellite imagery. PCA is also used for feature extraction and enhancement of images.

2.2 Study Area

The proposed road feature extraction algorithm is carried out on Sri Kalahasti town and its neighboring area region in Chittoor dst.of AP state, India. It has latitude of 13.7520° N and longitude of 79.7037° E.
in latitude of 13.2172°N and longitude of 79.1003° E of chittoor dst.

3. RESULTS AND DISCUSSIONS

False color composite (FCC) is obtained by False color composite (FCC) is obtained by fusion of various bands. Here we have fused 3, 4, 5 and 6 bands. FCC is used for supervised classification. FCC is shown in Fig. 2. Roads are not clearly visible in FCC. For road feature extraction BAI-PC and REI-PC are used. Fig. 3 shows BAI-PC before enhancement. Fig. 4 shows REI-PC before enhancement. Fig.5 presents BAI-PC before enhancement classification. Fig.6 describes REI-PC classification before enhancement. Fig. 7 shows BAI-PC after enhancement. Fig. 8 shows REI-PC after enhancement. Fig. 9 presents BAI-PC after enhancement classification. Fig.10 describes REI-PC classification after enhancement.

By using roads indices, the roads are enhanced and extracted properly. Table 4 presents quality performance measures for BAI-PC before enhancement. Correctness for Roads is 94%. Correctness for Non Roads is 90%. Completeness for Roads is 94%. Completeness for Non Roads is 90%. Quality and Redundancy for roads are 0.887% and 2.06 respectively. OA value is 91.33% and KC is 0.87. BAI is built-up index, so it gave less value for overall accuracy and Kappa Coefficient.

Table 5 describes presents quality performance measures for REI-PC. Correctness for Roads is 90.74%.Correctness for vegetation and urban are 97.87% and 90% respectively. Completeness for Roads is 98%. Completeness for vegetation and urban is 92% and 90% respectively. Quality and Redundancy for roads are 88.6% and 1.98 respectively. OA value is 91.67% and KC is 0.833. Overall accuracy and Kappa Coefficient are good values for REI-PC. REI is Road index, so we got good values for UA and PA compared to BAI-PC. Fewer pixels are misclassified in REI-PC compared to BAI-PC. So, proposed method able to extract roads with good visual quality.

Table 6 describes quality performance measures for BAI-PC after enhancement. Correctness for Roads is 94.12%.Correctness for vegetation and urban are 93.75% and 92.16 respectively. Completeness for Roads is 96%. Completeness for vegetation and urban is 90% and 90% respectively. Quality and Redundancy for roads are 0.888 and 2.06
respectively. OA value is 90% and KC is 0.87. Overall accuracy and Kappa Coefficient are good values for REI-PC after enhancement. REI is Road index, so we got good values for UA and PA compared to BAI-PC after enhancement.

Table 7 presents quality performance measures for REI-PC after enhancement. Correctness for Roads is 100%.Correctness for vegetation and urban are 94% and 96 respectively. Completeness for Roads is 98.04. Completeness for vegetation and urban is 97.87% and 92.31% respectively. Quality and Redundancy for roads are 0.891 and 2.1 respectively. OA value is 94% and KC is 0.89. Overall accuracy and Kappa Coefficient are good values for REI-PC after enhancement. REI-PC after enhancement is Road index, so we got good values for UA and PA compared to BAI-PC after enhancement.

The only disadvantage with REI-PC is redundancy is more. All the other quality performance metrics has got good values.

4. CONCLUSION

A novel algorithm is used to extract roads from satellite imagery. With this method roads are identified correctly. After contrast enhancement, BAI-PC and REI-PC are applied to Landsat-8 imagery. Supervised classification is performed. Finally, accuracy assessment has been performed with error matrix. The proposed novel algorithm gave better results in terms of qualitative parameters such as OA, KC, Completeness, Correctness, Quality, and Redundancy. The method is able to extract roads in satellite imagery.

ACKNOWLEGEMENT

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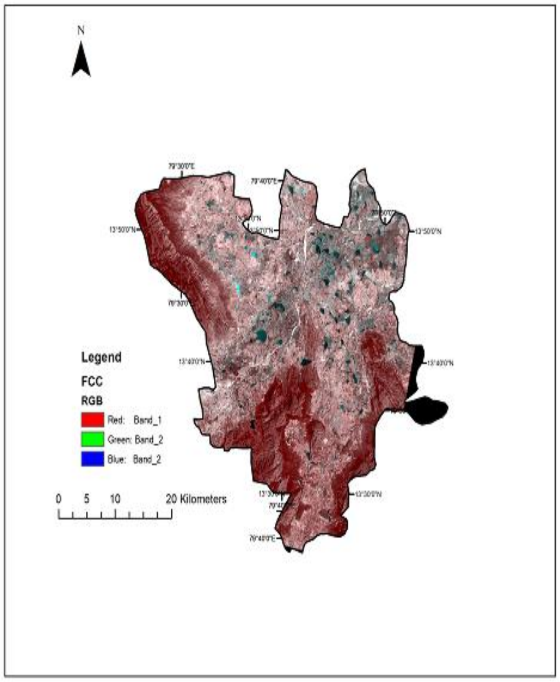

Fig. 2: FCC after fusion before enhancement

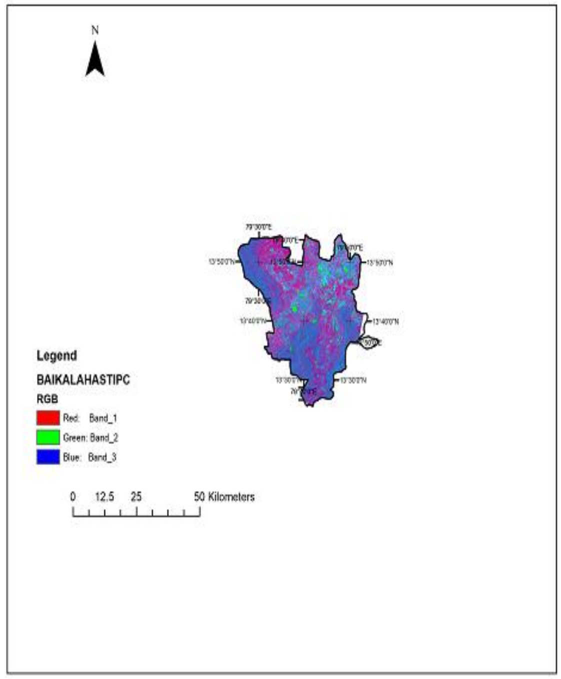

Fig.3: BAI-PC before enhancement

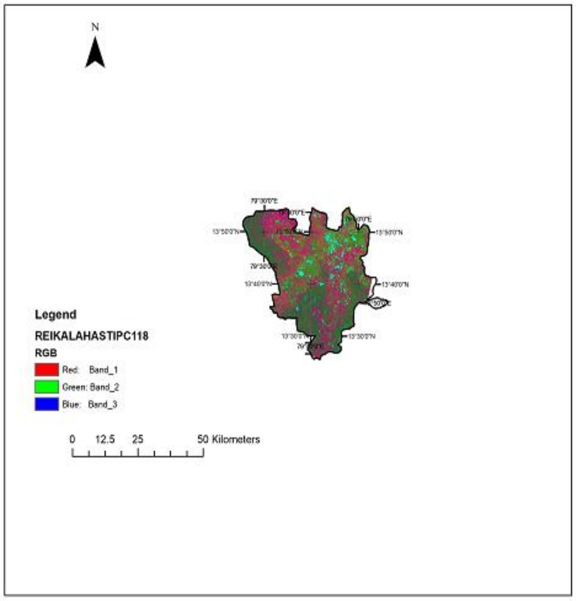

Fig. 4: REI-PC before enhancement

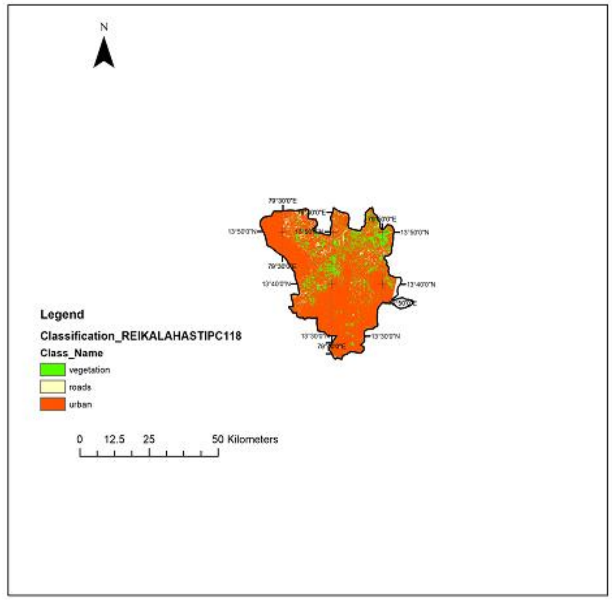

Fig. 5: BAI-PC classification before enhancement

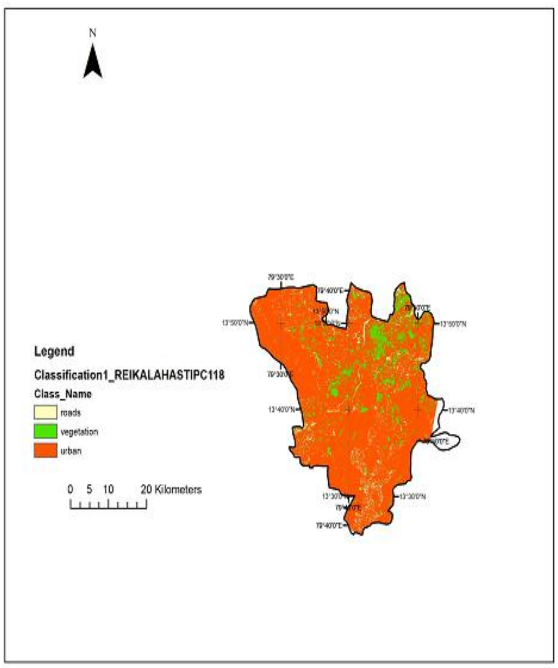

Fig. 6: REI-PC classification before enhancement

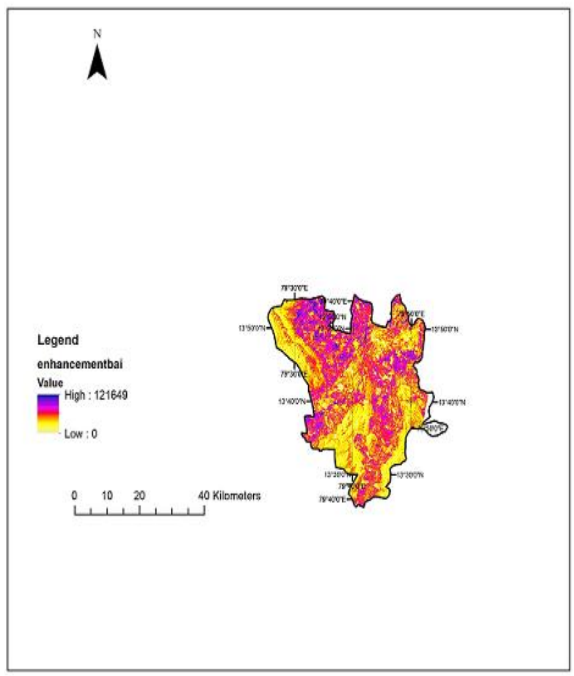

Fig. 7: BAI-PC after enhancement

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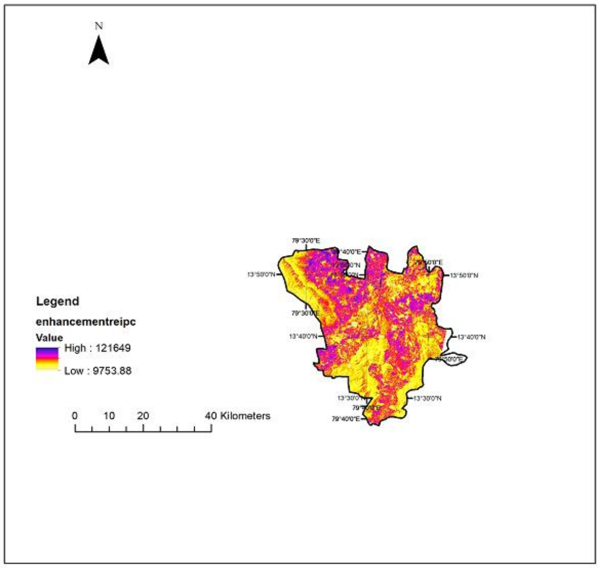

Fig. 8: REI-PC after enhancement

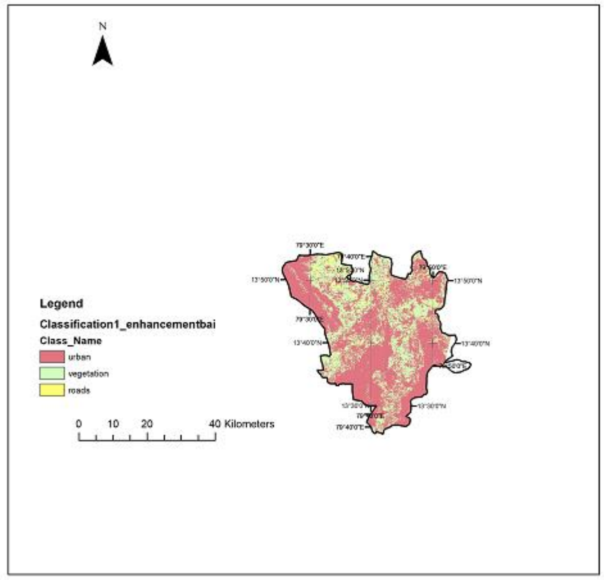

Fig. 9: BAI-PC classification after enhancement

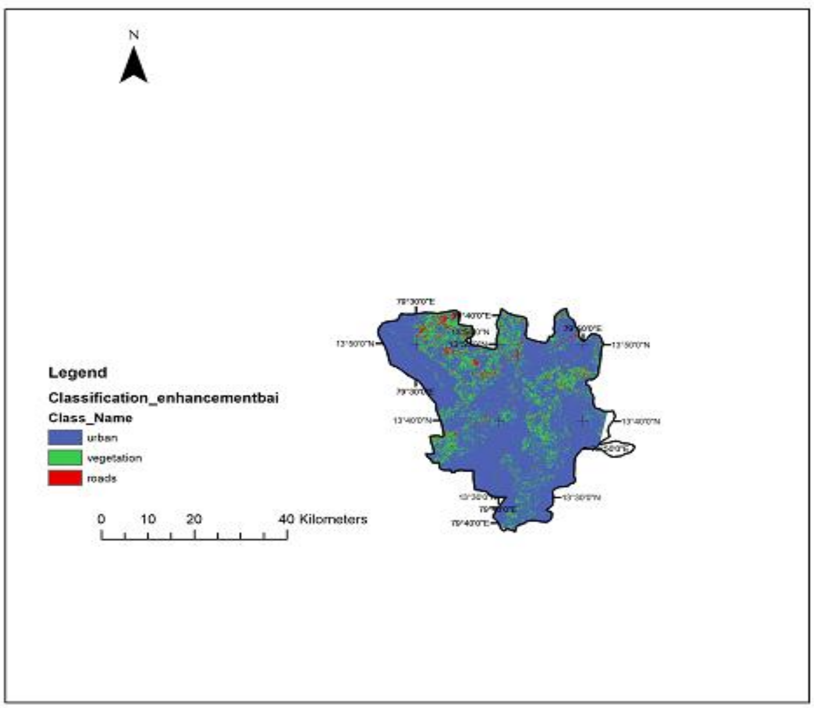

Fig. 10: REI-PC classification after enhancement

Table 4: Quality parameters for BAI-PC before enhancement

Land cover	Roads	Vegetation	Urban	Completeness (%)	Correctness (%)	Quality	Redundancy
Roads	**47**	1	2	94	94	0.887	2.06
Vegetation	2	**45**	3	90	90	0.818	2.11
Urban	1	4	**45**	90	90	0.818	2.11
O.A=91.33% K=0.87							

Table 5: Quality parameters for REI-PC before enhancement

Land cover	Roads	Vegetation	Urban	Completeness (%)	Correctness (%)	Quality	Redundancy
Roads	**49**	0	1	98	90.74	0.891	2.1
Vegetation	1	**46**	4	90.2	97.87	0.885	2.02
Urban	4	1	**45**	90	90	0.818	2.1
O.A=92.7% K=0.89							

Table 6: Quality parameters for BAI-PC after enhancement

Land cover	Roads	Vegetation	Urban	Completeness (%)	Correctness (%)	Quality	Redundancy
Roads	**48**	1	1	96	94.12	0.888	2.06
Vegetation	2	**45**	3	90	93.75	0.833	2.06
Urban	1	2	**47**	94	92.16	0.87	2.1
O.A=90% K=0.87							

Table 7: Quality parameters for REI-PC after enhancement

Land cover	Roads	Vegetation	Urban	Completeness (%)	Correctness (%)	Quality	Redundancy
Roads	**50**	0	1	98.04	100	0.891	2.1
Vegetation	0	**46**	1	97.87	92	0.885	2.02
Urban	0	4	**48**	92.31	96	0.818	2.1
O.A=94% K=0.89							

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