Classification and Extraction of Wetland Features Using Geoinformatics

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ABSTRACT

Wetlands play significant role in maintaining the ecological balance of both abiotic & biotic life in inland and coastal environment. Wetlands occur where the water is at or near the surface of the land, or where the land is covered by the water. Wetlands have great importance more than one reason, because they charge aquifers, conserve moisture, act as pollution filter and are habitat for diversity. Hence, understanding of their occurrence, spatial extent of change in wetland environment is very important and can be monitored using satellite Remote Sensing technique. Accurately mapping wetland type and monitoring their dynamic changes provide the scientific foundation for wetland protection and restoration.

The main aim of this study is to map and detect changes in wetland of study area using various digital classification techniques and compare accuracy of supervised & knowledge base classification. Spectral bands and spectral indices are used for extraction of wetland features. Indices are useful for delineating wetland features, and they are used in knowledge-based classification. A knowledge-based classification has been developed using decision tree approach for extraction of wetland features. Change detection analysis has been carried out to find change in wetland features. The study is carried out for pre monsoon and post monsoon period. It is observed that overall accuracy of knowledge-based classification is better than supervised classification.

Keywords: Knowledge Based Classifier, Spectral Bands, Spectral Indices, Supervised Classification, Wetland.

1. INTRODUCTION

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by water. Once treated as transitional habitats or seral stages in succession from open water to land, the wetlands are now considered to be distinct ecosystems with specific ecological characteristics, functions and values.[1] Wetlands are dynamic environments existing at the terrestrial-aquatic interface. As such, they are vulnerable to a wide range of human-mediated environmental and hydrological alterations associated with population growth, urbanization, and increased human development activities[2]. Wetlands are complex systems with a high presence of water and both natural and artificial surfaces. Thus, mapping wetlands and monitoring their changes over time is a challenging procedure, especially using multispectral imagery for this purpose. [3]

"Remote Sensing is the science of making inference about objects from measurements, made at a distance, without coming into physical contact with the objects under study". However the term Remote Sensing is used more commonly to denote identification of earth features by detecting characteristic electromagnetic radiation that is reflected or emitted by the earth system.[4] Remote sensing offers a cost-efficient means for identifying and monitoring wetlands over a large area and at different moments in time.[5] Spatially and thematically explicit information of wetlands is important to understanding ecosystem functions and services, as well as for establishment of management policy and implementation. [6]

The LISS-III is a multi-spectral camera operating in four spectral bands with spatial resolution of 24m, which are 0.52-0.59 microns (B2-Green), 0.62-0.68 microns (B3-Red), 0.77-0.86 microns (B4-NIR) and 1.55-1.70 microns (B5-SWIR). The blue-green (0.50-0.60 μm) region of the spectrum corresponds to the chlorophyll absorption of healthy vegetation and is useful for mapping detail such as depth or sediment in water bodies. Cultural features such as roads and buildings also show up well in this band. Chlorophyll absorbs Red (0.60-0.70 μm) wavelengths in healthy vegetation. Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries. The near-IR (0.70-0.80 μm) is especially sensitive to varying vegetation biomass. It also emphasizes soil-crop and land-water boundaries. The second near-IR (0.80-1.10 μm) band is used for vegetation discrimination, penetrating haze, and water-land boundaries. The Mid-IR (1.55-1.74 μm) (B5-SWIR) is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice.[7]

The process of sorting or arranging entities into groups or categories on a map is known as classification.[8]Various Classification techniques arebeing used in GIS and remote sensing to generalize complexity and extract meaningful information from geospatial data along with application of algorithms.Unsupervised image classification, Supervised image classification and Object-based image analysis are the 3 main types of image classification techniques in remote sensing.

2. OBJECTIVE

The main objectives of the present study are to detect changes in wetland features for Pre monsoon & Post Monsoon period and to compare the results of supervised classification and knowledge based classification.

3. STUDY AREA

For the present work the Surendranagar district, Gujarat state, India has been chosen for investigation. Location map shown in Fig.1. Surendranagar is an administrative district of Gujaratwith its headquarters located at the same city of Surendranagar.

The district occupies an area of 10,423 sq. km with total population of 1,756,268 according to 2011 census. Nal Sarovar a famous bird sanctuary is located in the district having spread of the area of 120.82-sq-km, which is also declared as a Ramsar site on 24 September 2012. Ramsar Convention is an international treaty for the conservation and sustainable use of wetlands.

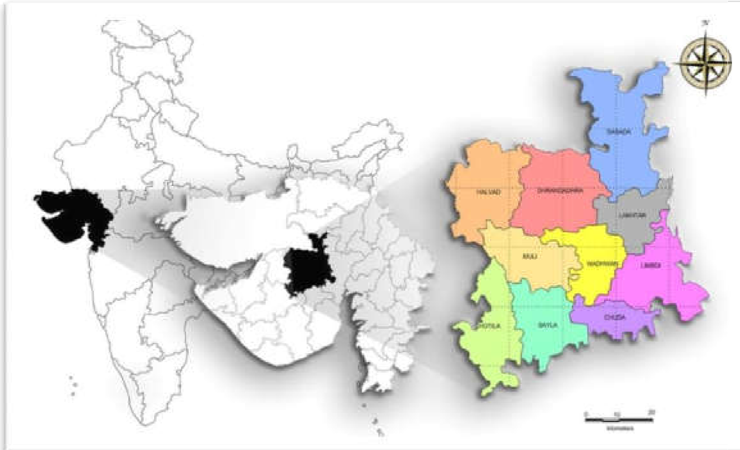

Figure 1. Location Map of Surendranagar (Source: Administrative division, Surendranagar)

4. METHODOLOGY

Surendranagar district is located in the north western part of Saurashtra Peninsula of Gujarat State. A major portion of the district is drought prone. This district is an underdeveloped district having diverse terrain conditions and varied but limited endowments of nature. [9]Despite of having wetland in neighboring area the district is drought prone.

Various techniques have been opted on experimental bases for the classification of the wetlands using satellite images and geoinformatics. The kind of the data used/available and the desired outcome are major governing factors for the selection or development of a particular classifier. It has been a technical challenge to accurately detect urban wetlands with remotely sensed data by means of pixel-based image classification.[10]Understanding of spatialinformation along with spectral information has been seenwith improvedclassification accuracy. Knowledge-based classification,withgreat potential to overcome or reduce these technical impediments,has been applied to various image classifications focusing on urban land use/land cover and forest wetlands, but rarely to mapping the wetlands in urban landscapes.[10]

IRS-R2 (Indian Remote sensing- Resourcesat 2) LISS III data is used to map the wetlands of Surendranagar. LISS III provides data in 4 spectral bands: green, red, Near Infra Red (NIR) and Short Wave Infra Red (SWIR), with 23.5 m resolution and 24 days repeat cycle. Table 1 shows details of remote sensing data used for carrying out the study. Multi-temporal satellite data is used for monitoring land use/cover in the study area. Satellite imagesare acquired to capture the pre monsoon and post monsoon hydrological variability of the wetlands.

Table 1. Details of Satellite Image
http://vedas.sac.gov.in:8080/SDIS_Web/Sdis_Query.jsp

Name of Satellite	Sensor	Spatial Resolution	Band	Swath	Date
IRS II	LISS III	23.5 m	Band 2: 0.52-0.59 mm Band 3: 0.62-0.68 mm	141 km	19/03/2016

IRS II	LISS III	23.5 m	Band 4: 0.77-0.86 mm Band 5:1.55-1.70 mm	141 km	14/11/2016

The area of interest extracted from the downloaded image, for processingthe extracted part rather than processing the whole image with the objective to save time and memory space.Image interpretation and examination taken up for the purpose of identifying object and judging their significance. Hence, efforts are made to understand logical processes in detecting, identifying, classifying, measuring and evaluating the significance of various features, their patterns and spatial relationships (Fig. 2).

The study is done in three folds:

- Extraction of wetland features using supervised classification and wetland area estimation using GIS (Fig. 3),
- Extraction of wetland features by developing knowledge-based classifier and wetland area estimation,
- Comparison of bo h techniques by accuracy assessment.

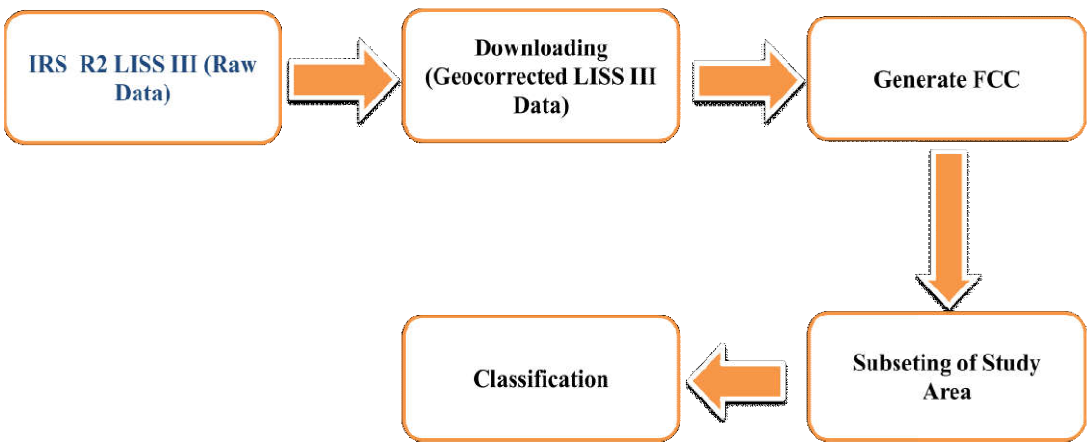

Figure 2. Data acquisition and pre-processing

Classification is a process of identification and grouping of objects or features. It arranges "repetitive features" in the same class to which the features belongs. Supervised classification is based on the spectral characteristics of features.

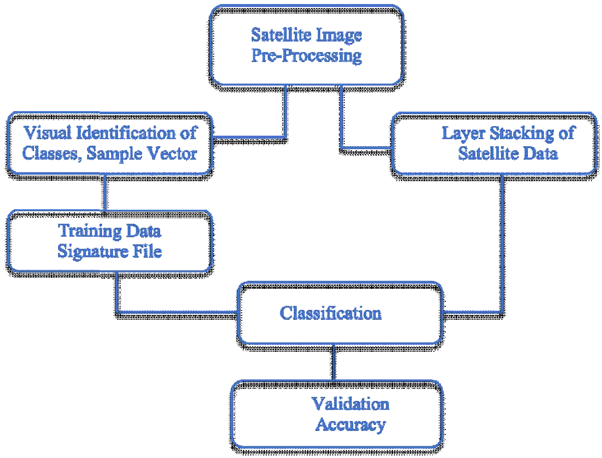

Figure 3. Process Flow for Supervised Classification

In the process of training the set of pixels from the image are extracted for the classifier, which is popularly known as signature set.Utmost care is taken to ensure that signature lies in features of single class that it did not spread up to another class region. For improved results more numbers of signatures from different place for same class are marked and merged to a single class as shown in Fig. 4.

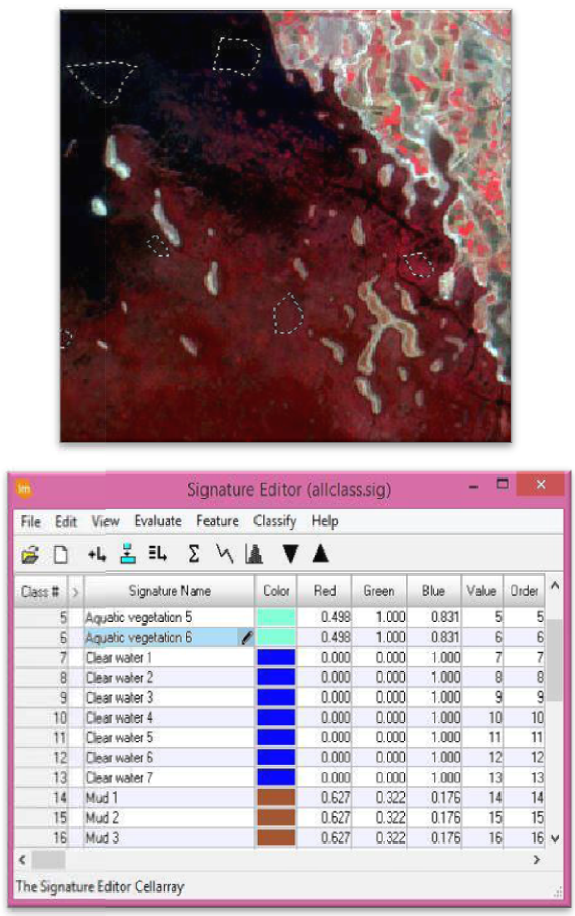

Figure 4. Training stage, sample collection and Signature generation

For performing the supervised classification, Maximum Likelihood Algorithm is preferred over other algorithms because it involves maximizing a likelihood function in order to find the probability distribution and parameters that best explain the observed data.Classified images of LISS III data over the area of Surendranagar for pre monsoon and post monsoon are shown in Fig. 5. LISS III data has been classified into three wetlands features namely water, mud flats and aquatic vegetation. Water has three sub features i.e. Low turbid water, Moderate turbid water, High turbid water.

Knowledge based classifier is a non-parametric ruled based classifier, which differentiates the features based on the rules developed by the knowledge from all sources (Visual interpretation, DEM, Statistical Analysis, geomorphology etc). Knowledge based classifier is a decision tree classifier which does not presuppose any assumption related to the distribution of the data.

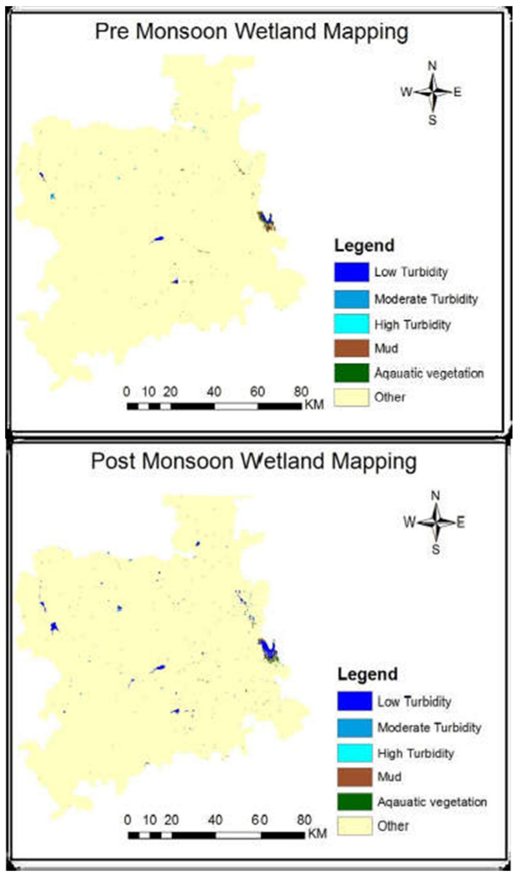

Figure 5. Supervised Classification images of LISS III data over the area of Surendranagar

The knowledge based method is used for the automatic delineation of wetland feature categories such as water spread, wetland area, turbidity and wetland vegetation as shown in Fig. 6. Using the information contained in the ancillary layer, decision rules are developed to classify the classes of interest.Spectral knowledge of Green, Red, NIR and SWIR band is crucial for classifying the wetland features. In conjunction with these bands, spectral values and indices have also been used for classifying all the wetland features by developing knowledge based classifier.

Spectral indices are generally computed by rationing, differencing, summing, linearly combining data from two or more spectral bands. They are dimensionless and radiometric measures that are expected to minimize the solar radiance and also it improves the spectral signature. The use of spectral indices can normalise the effects of differential illumination of features and also helps in the extraction of features of interest in an area.

Five indices namely Normalised Difference Vegetation Index (NDVI), Normalised Difference Water Index (NDWI), Modified Normalised Difference Water Index (MNDWI), Normalised Difference Pond Index (NDPI) and Normalised Difference Turbidity Index (NDTI) are generated for both pre and post monsoon satellite imagery using the following formulas.

- NDVI: (NIR – Red) / (NIR + Red)
- NDWI: (Green – NIR) / (Green + NIR)
- MNDWI: (Green - MIR) / (Green + MIR)
- NDPI: (SWIR – Green) / (SWIR + Green)
- NDTI: (Red – Green) / (Red + Green)

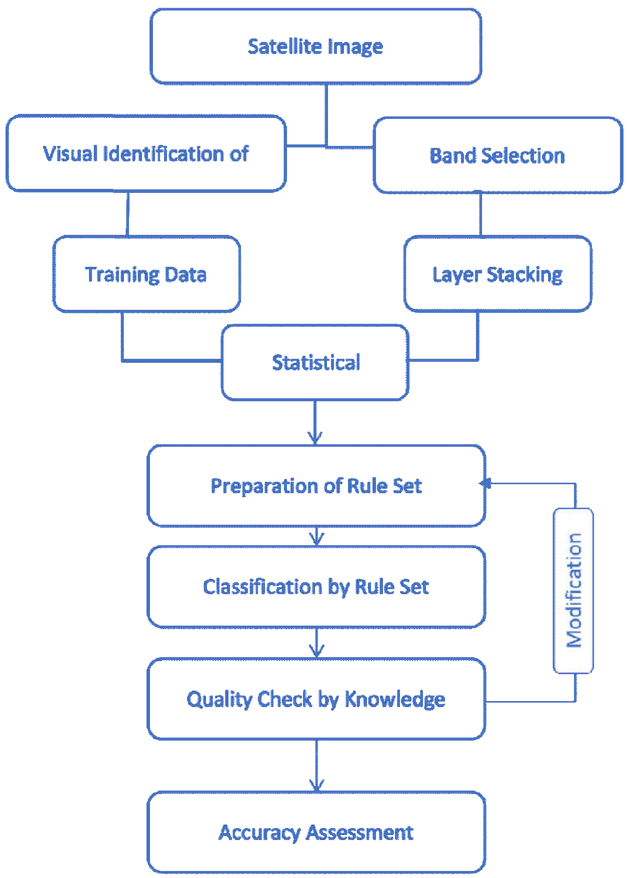

Figure 6. Process Flow for Knowledge Based Classification

The images generated for indices used in this study are as shown in the Fig. 7.

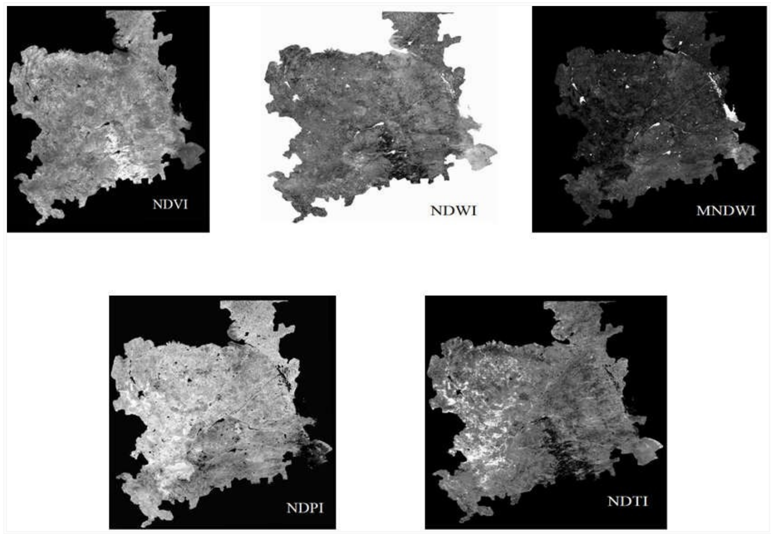

Figure 7. Indices calculated for the study area

To build one multi information layer for finalizing the radiance ranges in all the spectral bands and indices, all the nine layers are stacked together. This stacked image containing all the relevant information about each parameters is finally used for knowledge based classifier development. By visual inspection and statistical analysis,ranges for the radiance in Green, Red, NIR, and SWIR bands and indices values have been finalised for bothpost monsoon & pre-monsoon seasons.

Out of this knowledge rules are set from ASCII values of stacked layers the decision tree is finalised. The task of creating a useful, well-constructed knowledge base required numerous iterations of trial, evaluation and refinement.

Once the classification rules are generated using decision tree classifier, they served as a knowledge database. This knowledge base is used for classification of the satellite images. Three approaches are followed to use the extracted classification rules for the classification. In first approach, classification rules are used directly using knowledge base classifier to classify the image. In Second approach prior probability of the class distribution is used to classify the image. A new method is proposed to calculate the prior probability from already classified image using first approach. In third approach, post-classification sorting method is used to reclassify the pixels, which are misclassified during maximum likelihood classification.

5. RESULTS & DISSUCISION

The results of accuracy assessment done for supervised classification performed on Pre-Monsoon and Post-Monsoon seasons data, shows that the accuracy is 90% and 86.67% respectively, whereas the Kappa Statistics are observed to be 0.8800 and 0.8400 respectively.Similarly, the accuracy assessment performed for Knowledge Based Classification on Pre-Monsoon and Post-Monsoon seasons data, shows that the accuracy is 95.00% and 93.33% respectively, whereas the Kappa Statistics are observed to be 0.9400 and 0.9200 respectively. Total overall classification accuracy of knowledge classifier is 95% while for supervised classifier it is 90%as shown in Fig. 8.

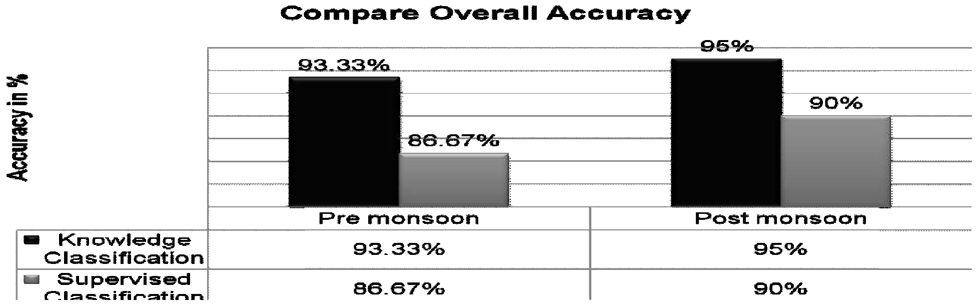

Figure 8. Compare Accuracy of Supervised & Knowledge Based Classification

Overall classification accuracies of all features using both methods, supervised classification and knowledge based classification have been plotted. It can be concluded from below graphthat during Pre monsoon season (Fig. 9), Knowledge based classifier classifies features with better accuracy. Comparative study shows that for pre monsoon period, knowledge based classifier perform good for extracting the concerned wetland features.whereas in the case of post monsoon period,knowledge based classifier have not performed good for Wetland vegetation feature(Fig.10).

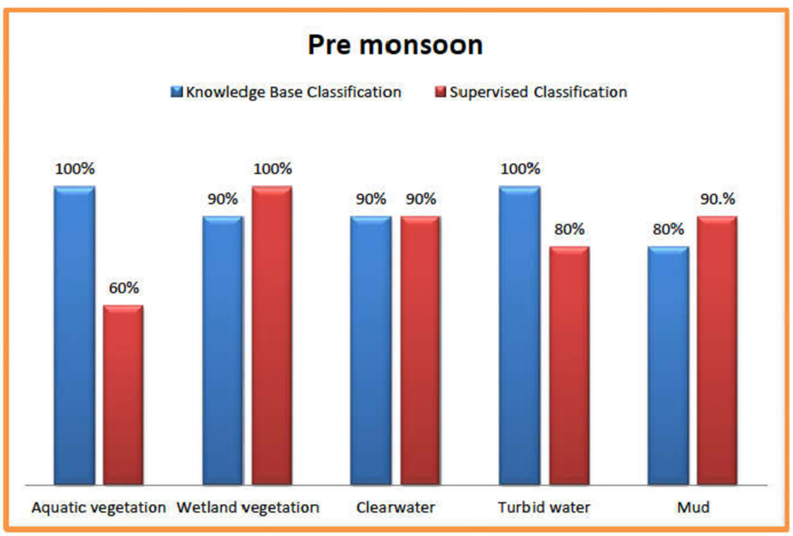

Figure 9. Overall Accuracies obtained using Supervised and Knowledge based Classification (Pre monsoon)

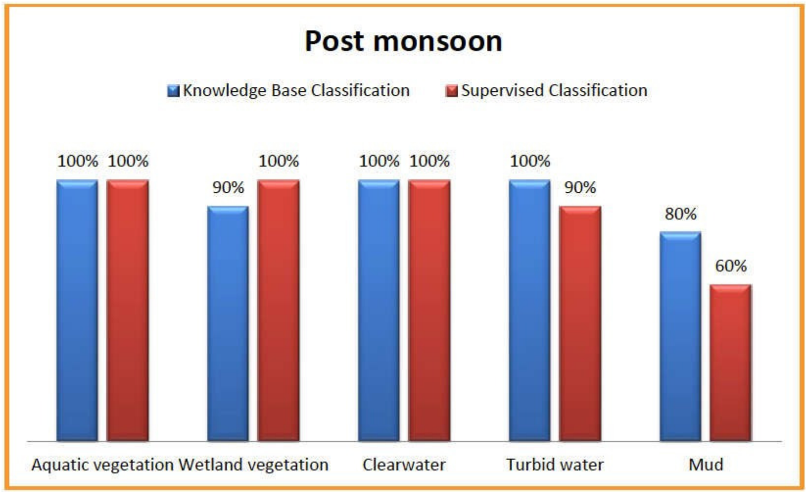

Figure 10. Overall Accuracies obtained using Supervised and knowledge based Classification (Post monsoon)

The total area of wetland in pre monsoon season for Surendranagar by the supervised classifiedand knowledge based classification is estimated. It is clear from the Fig. 11, 12 and 13, that the area for overall wetland features is increased in post monsoon. For the supervised classification the area of turbid water and mud has reduced whereas for knowledge based classifier the area of aquatic vegetation and turbid water has reduced.

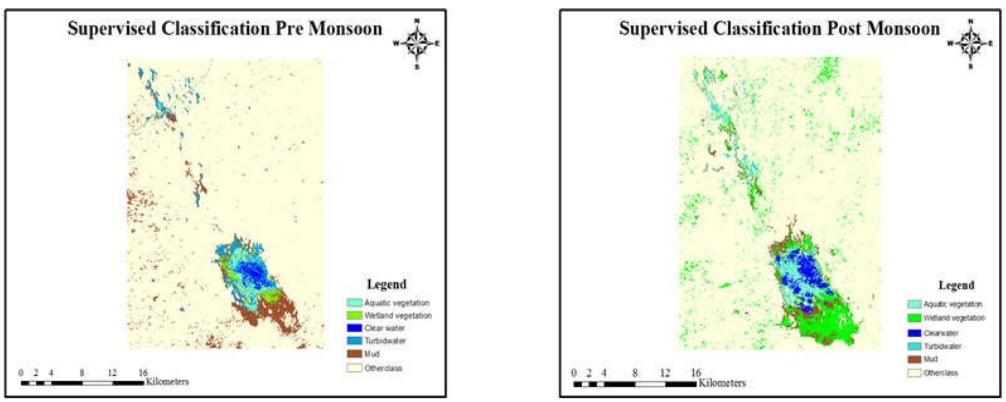

Figure 11. Supervised Classification (Nal Sarovar)

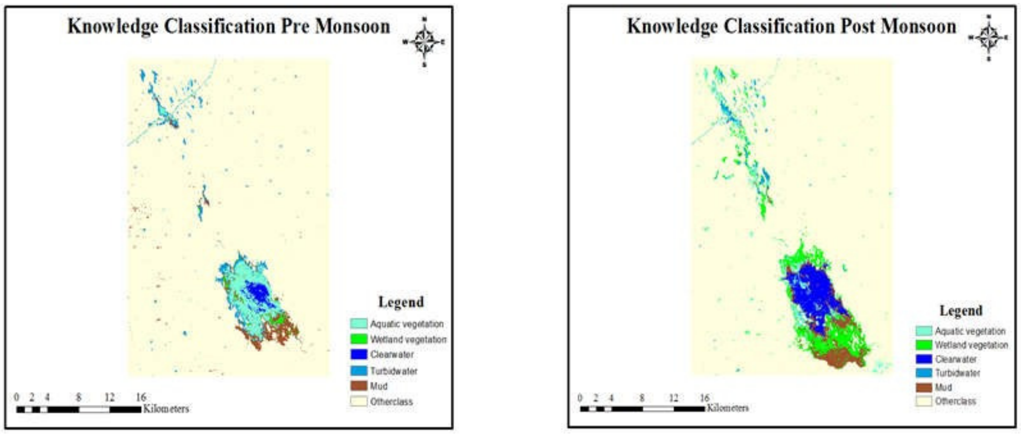

Figure 12. Knowledge Based Classification (Nal Sarovar)

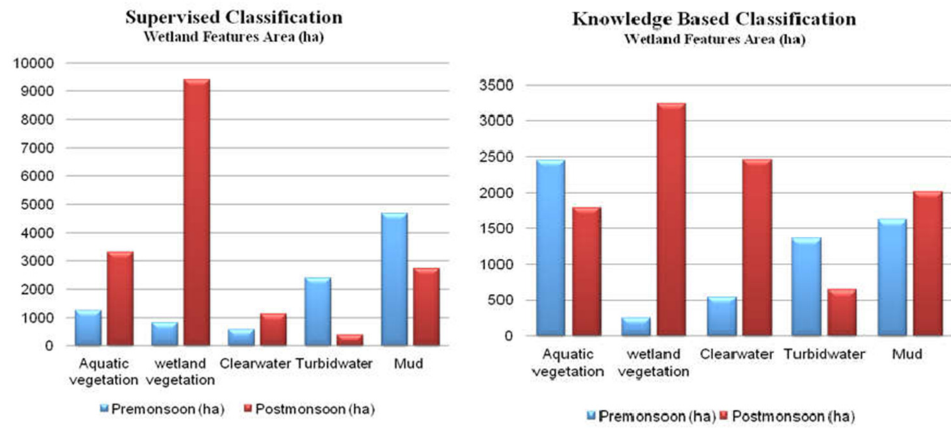

Figure 13. Comparison of Wetland Features Area for Pre Monsoon& Post Monsoon

6. CONCLUSION

LISS III data of Surendranagar have been classified using supervised classification as well as by developedknowledge based classifier.Overall conclusion of the study is that knowledge based classifier can give better result than supervised classification.The results of total area of the wetland estimated for Surendranagar by the supervised classified and knowledge based classification shows that theoverall wetland areahas increased in post monsoon.

7. ACKNOWLEDGEMENT

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