Detecting Mangrove Forests in Sundarbans using different Image Classification Methods and Change Analysis

Yamini Ratawal, Sameer Arora, Sagar malik, Pranay Anand, Shivam Sharma
Department of Computer Science Engineering
Dr. Akhilesh Das Gupta Institute of Technology and Management
Delhi, India
(yaminiratawal26@gmail.com, sameerarora0203@gmail.com, sagarmalik2582@gmail.com, pranayanand.sm@gmail.com, shivam123sharma12@gmail.com)

Abstract:

Satellite or Remote Sensing Images are taken from USGS Earth Explorer website of category Landsat-8 band Images of mangrove forest areas in Sundarbans. Different classification methods - unsupervised classification with k-means clustering, supervised classification using the maximum likelihood decision rule are used to classify the Landsat Images. Our results concluded that a supervised classification method is better than unsupervised classification in terms of accuracy calculated for each and every class of the image.

Further, we have calculated the change in mangrove forest cover over the past 6 years because various factors such as permanent erosion and deforestation have taken place and many reports pointed towards the loss of mangrove forest cover. We have done our case study as per the reports of the Forest Surveys of India (FSI) and concluded our results in percentage changes year wise and in the form of image visualization of the land affected.

1. Introduction

The appraised global coverage of mangrove forest is 137,760 km^2, this equates to 0.1% of the earth's surface. The Sundarbans, the largest contiguous mangrove forest in the world, is considered as a site of national and international importance for the conservation of biodiversity. The Sundarbans covers an area of approximately 10,000 km^2 and lies in the territory of Bangladesh and India. Mangroves are the unique ecosystem that provides a wide range of ecosystem services and contributes to socio-economic development of the neighboring communities and the country. Timber, fisheries and other non-timber forest products (NTFP) are the main products of the forest. This forest has enormous ecological and economic importance at local, national and global scales. The Sundarbans plays an important role in the local as well as global ecosystem by absorbing carbon dioxide and other pollutants from air and water, offering protection to millions of people in the Ganges Delta against cyclone and water surges, stabilizing the shore line, trapping sediment and nutrients, purifying water, etc. Over 3.5 million of people living around the Sundarbans are directly or indirectly dependent on ecosystem services.(Ghosh, Kumar, & Roy, 2016).

2. Study Area

The Sundarbans mangroves forest is located in the southern coast of Bangladesh and India. The Bangladesh part of Sundarbans covers about 6000 sq.km, the other 4000 sq.km of the forest is located in India. This study considers the Indian part of the Sundarbans only. This forest is located on the Ganges Delta created by the confluence of three mighty river systems, Ganges, Brahmaputra and Meghna, at the northern limit of the Bay of Bengal and it extends between approximately 21°32′ to 22°40′ N latitude and 88°05′ to 89°51′ E longitude. The Sundarbans is crisscrossed by a complex network of river channels and comprises a number of mudflats and small islands. These small islands and mudflats are created as a result of the sedimentation process that is influenced by the river system intersecting this forest. This forest region is characterized by a tropical climate with four main seasons that include pre-monsoon (March to May), monsoon (June to September), post-monsoon (October–November) and dry winter (December to February). Rainfall and temperature fluctuate between 1600 mm and 2000 mm and 11 °C and 37 °C, respectively in this region, while elevation varies between 0.9 and 2.11 m above sea level.(Sundarbans)

Figure 1. Study Area(Indian Sundarbans)

3. Mangrove Plantation and Deforestation:

The coastal areas of sundarbans are prone to cyclones and during the latest cyclone hit that made landfall near Sagar island as a result on World Environment Day in 2020, Bengal Chief Minister announced to plant nearly 50 million mangroves in the Sundarbans.(Basu, 2020) Healthy mangrove forest vegetation is very important in sundarbans as it works as a barrier to high-density cyclones that impact the islands and even delta areas including Kolkata.

The Indian Sundarbans are spread over 9630 sq km, and around 28 per cent of the Sundarbans had been damaged by cyclones affecting mangrove population badly in the past few years. The loss of land due to erosion is leading to direct loss in the mangrove forests. As a result affecting the livelihood in Sundarbans and climate changes.(Ghosh, 2020)

4. Data and Methodology:

4.1. Data

Landsat-8 images (band 1, 2, 3, 4, 5, and 7) were downloaded from the website of the Global Land Cover Facility of USGS Earth Explorer. As described in the following sections, it was observed after trying with multiple band combinations that to best classify between dense(mangroove) and low vegetation(non-mangroove) can be achieved using B5/B4/B3(band 5/band 4/band3) combination. (Natural and False Color Composites) The stacked image generated by the combination of the bands mentioned above represents the natural color image in which the more dense and darker the color the more is the dense vegetation in that area. The image is shown below.

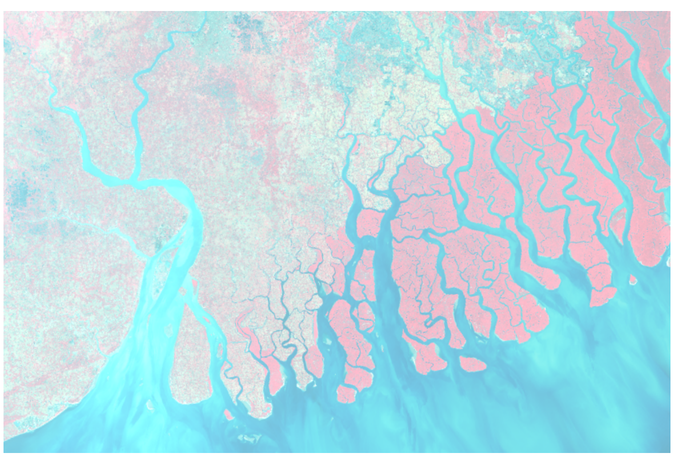


Figure 2. Stacked Natural Color Image.

4.2. Methodology:

The methodology of this study is given in the following flow chart and the detailed study of the classification methods used, accuracy assessments and conclusions obtained are explained in the following sections.

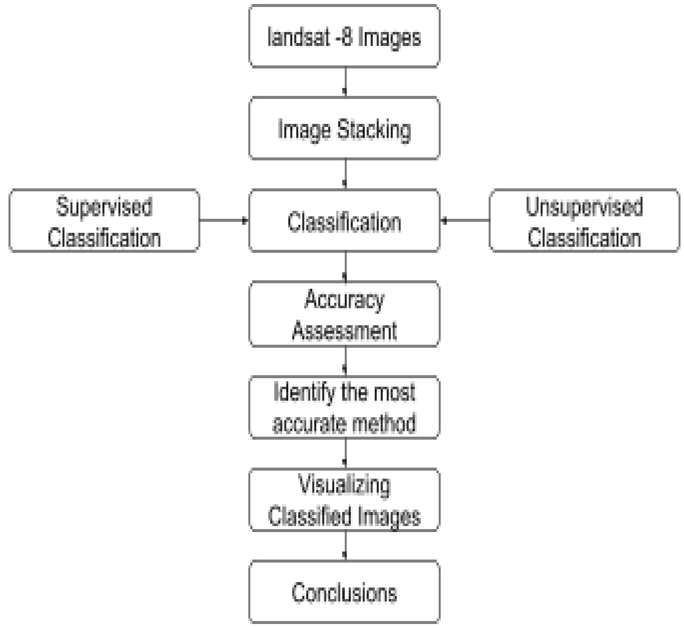


Figure 3: Methodology Flow Chart

5. Image Classification:

In reference to legend systems for land-cover mapping, such as the United States Geographical Survey (USGS) Land Use/Land Cover System Legend, here we have classified the image broadly into five legends(categories): mangrove forest, low vegetation, bare land(crop land), land and water. Details of each category are mentioned below. In this study we compare the outcomes of supervised, unsupervised classification methods to find the best and most accurate way to extract mangrove forest in Sundarbans. (Rahman, Rahman, & Lan, 2013)

5.1. Supervised Classification:

It is observed in most situations that supervised classification yields better results than unsupervised classification when training areas are provided accurately and precisely. Here, we have employed supervised classification using maximum likelihood decision rule, which is widely used in satellite image classifications. The training pixels in terms of polygon shapefiles are closely chosen in reference to Google authorized sources such as Google satellite images, photographs, maps, etc. The number of training samples and size of each sample is chosen in accordance to the given classes. Usually 3 samples per class are sufficient but if the class has higher variability across the image than more samples will be needed. (Rahman, Rahman, & Lan, 2013)

5.2. Unsupervised Classification:

Image is classified using unsupervised classification. The k-means clustering algorithm is used to produce 20 user-defined classes with the maximum of 10 iterations. The resulting classes are then closely compared with the field data and appropriately merged so as to obtain the required five classes. The results and accuracy of each classification is discussed in the further sections. (Rahman, Rahman, & Lan, 2013)

TABLE 1. Land Cover Classes

Land cover/ class	Description
Mangrove	Tidal Forests found near the sea shore.
Low Vegetation	Area consisting of small trees, plants, shrubs, etc.
Bare/Crop Land	Land covered with agricultural crops.
Land	Residential, industrial and commercial complexes.
Water	Land covered with rivers, lakes, bays and estuaries.

5.3. Accuracy Assessment:

Determining the accuracy of the classified images is one of the key components to validate our observations. So, the accuracy of the classified images is carefully inspected in a systematic manner by dividing the area into polygon shaped blocks for which comparison is made on a random basis with the authorized sources such as google satellite images generated from Google Earth. After generating reference polygons, each polygon is visually inspected against a live google map, google earth images and local photographs.

In addition to visual inspection, the random sampling method using the reference data generated with polygons is employed to perform the accuracy assessment of supervised, unsupervised classification separately. The samples are chosen arbitrarily for each class and each sample is approximately of the size of 300 pixels. After completing the accuracy assessment, results generated in the form of an error matrix consist of the producer's accuracy, user's accuracy, kappa statistics and overall accuracy which are given in the following tables. (Congalton, 2003)

Table 2. **Comparisons of all land-cover classes by different classification methods**.

	Type of classification			
	Unsupervised		Supervised	
Class name	Area (km)	Area (%)	Area (km)	Area (%)
Mangrove forest	19,686.55	37.46	20,664.39	39.33
Water	22,028.06	41.92	21,187.98	40.32
Bare land	1,411.91	2.68	4,761.26	9.06
Low Vegetation	5,708.08	10.86	4,280.19	8.15
Land	3,664.15	6.97	1,646.78	3.13

Table 3. Error matrix showing classification accuracy of unsupervised classification.

Class	Class 1	Class 2	Class 3	Class 4	Class 5	Classified total
Class 1	372	0	3	0	0	375
Class 2	0	903	0	4	0	907
Class 3	0	0	118	4	0	122
Class 4	0	0	0	140	11	151
Class 5	0	0	0	26	90	116
Reference Total	372	903	121	174	101	1617

Overall classification accuracy = 78.37%

Note: Class 1, Mangrove Forest; Class 2, Water; Class 3, Bare Land; Class 4, Low Vegetation; Class 5, Land.

Table 4. Error matrix showing classification accuracy of supervised classification.

Class	Class 1	Class 2	Class 3	Class 4	Class 5	Classified total
Class 1	370	0	1	0	0	371
Class 2	0	894	0	0	0	894
Class 3	2	0	99	0	2	103
Class 4	0	0	1	121	0	122
Class 5	0	9	0	0	103	112
Reference Total	372	903	101	121	105	1602

Overall classification accuracy = 85.49%

Note: Class 1, Mangrove Forest; Class 2, Water; Class 3, Bare Land; Class 4, Low Vegetation; Class 5, Land

6. Results:

6.1. Results from classification methods:

Each classification approach produces a classified land-use and land-cover image. However land-use area for some classes derived in supervised approaches shows small differences in terms of distributions of pixels as compared to the unsupervised approach. The classified images obtained are shown below. (QGIS)

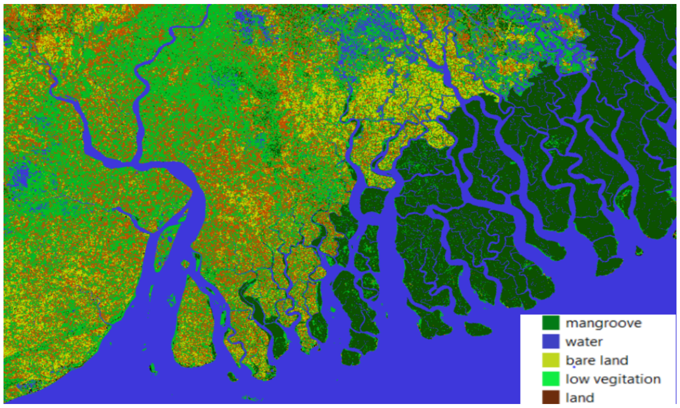


Figure 4. Unsupervised classified Image.

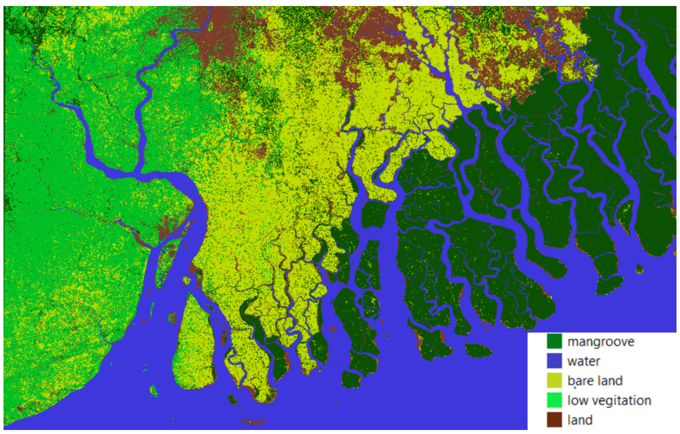
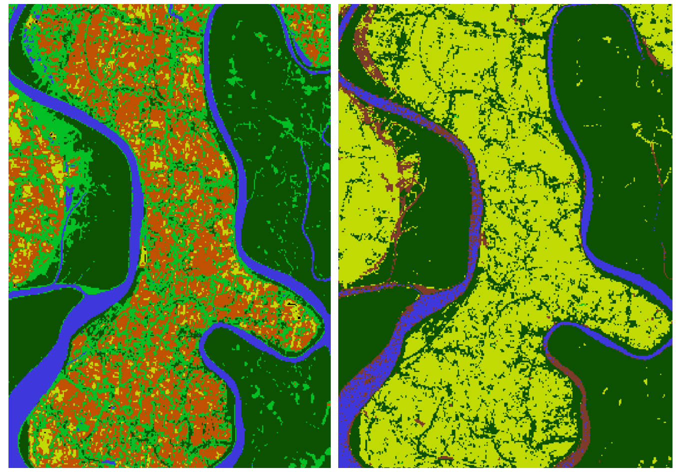


Figure 5. Supervised classified Image.

6.2. Results from accuracy assessment:

In addition to visual inspection, the sampling method to visualize and compare accuracy between supervised and unsupervised classification methods is also performed. Some outcomes of the samples identified are shown below. As a result, it is observed that some parts of crop lands, vegetation and land classes are misclassified in the unsupervised classification results.

The accuracy of classification can often be degraded due to areas that are not uniform, especially due to the coexistence of mangrove, crop land and commercial land areas together as what is also observed more in unsupervised classification. So, it can be concluded after observing major accuracy and visual assessments that supervised classification produces better results than unsupervised classification methods.



(a1) Unsupervised **(b1) Supervised**

Visual comparison : (a1) unsupervised classification image; the red patches show some misclassified pixels as compared to (b1) supervised classification image

The results of the random sampling method shows the overall accuracy of the supervised and unsupervised classification method as 85.49% and 78.37% respectively. Therefore, it is concluded that highest overall accuracy is obtained in the case of supervised classification method.

On closer observation of the error matrix and visual comparison (Congalton, 2003) of the two classified images, it was found that the image was mainly misclassified as natural(less dense) forest and cropland and main reason behind it can be non-uniform distribution and co existence of multiple classes as it is quite visible also in the classified images.

6.3. Results of Change Analysis over the years

After successfully determining the best classification method we have classified different images of years ranging from 2015 - 2020 and we have concluded the following changes occurred in classes taken.

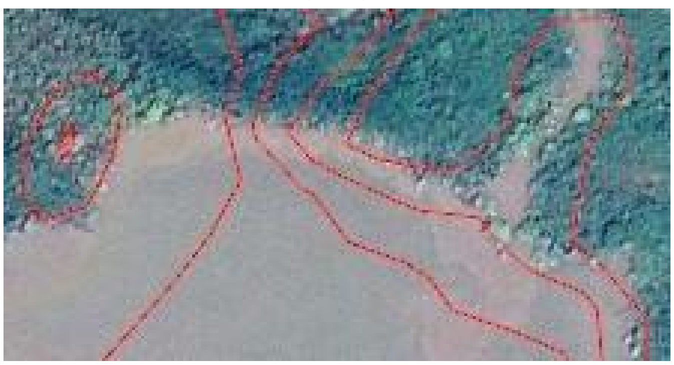
Table 5. Composition of different classes

Class	2015	2016	2017	2018	2019	2020
Class 1	49.%	40.1%	39.3%	36.5%	43.2%	49.0%
Class 2	40.%	40.6%	40.3%	40.3%	39.8%	39.3%
Class 3	7.6%	8.77%	9.06%	8.77%	9.11%	5.63%
Class 4	1.0%	7.56%	8.15%	10.7%	3.72%	1.38%
Class 5	1.0%	2.89%	3.13%	3.55%	3.99%	4.53%

Note: Class 1, Mangrove Forest; Class 2, Water; Class 3, Bare Land; Class 4, Low Vegetation; Class 5, Land

As visible in the table mentioned above, there was a decline in Mangrove Forest cover from 2017 as a result of cyclones and erosion caused in the areas of Sundarbans. Other main reasons for decline of the Mangrove areas in Sundarbans are widening of the rivers and rise in water level in Bay of Bengal. (Ghosh, 2020). Visual results of the change observed in the Mangrove areas are shown below between the years of 2017-2018.
The following images are the result of NDVI segregation of 2018 over 2017.

(2017)



(2018)

Figure-6: Difference in Mangrove area cover between 2017-2018 caused due to erosion.

7. Conclusions:

In this study, we have observed the effectiveness of different classification methods for classifying the landsat images generated from the USGS Earth Explorer website. It was observed that in comparison with the unsupervised classification using k-means clustering algorithm, supervised classification using maximum likelihood decision rule performed better and showed more accurate and precise results.

This study of remote sensing can help in providing continuous monitoring of mangrove over time. The findings of the research can suggest suitable techniques to classify and identify the changes occurring in the Sundarbans which can provide a strong foundation for future mangrove plantation and conservation acts.

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