ISSN: 2347-5129
IJFAS 2014; 1(5): 134-143

www.fisheriesjournal.com
Received: 02-03-2014
Accepted: 07-04-2014

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Aquaculture planning through Remote Sensing Image analysis and GIS tools in Northeast region, Bangladesh

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Abstract
The study was conducted to detect the land use changes using Remote Sensing (RS) images and Geographical Information Systems (GIS) tools for aquaculture planning in Trishal Upazila, northeast region of Bangladesh. Landsat TM image of 1999 and Google image of 2012 were used in the study. Normalized Difference Vegetation Index (NDVI) and Cluster image was prepared for discriminating the vegetation and for unsupervised image classification respectively. The unsupervised Landsat TM image of 1999 interpretation showed that total bare land and water body were 212 km^2 and 8 km^2 respectively. However, the bare land has decreased to 115 km^2 and the water body increased to 74 km^2 in Google image 2012. By contrast, the vegetation has increased 10% in NDVI Google image of 2012 than the Landsat TM image of 1999. Therefore, it is evident that 66 km^2 (28%) of water body has increased in 2012 Google image than the 1999 Landsat TM image, that means land use has changed tremendously in the study area over the fourteen years. It is also noted that vegetation has increased in the area due to water availability round the year in the region as fish ponds are everywhere. However, the conversion will only be permitted when follow the planning rules and integration of fish with agriculture is done.

Keywords: Land use change, Satellite image, unsupervised image classification, aquaculture planning.

1. Introduction

Bangladesh is a developing country in South East Asia with a comparatively low natural resource base, but a high growth rate of population, depends mainly on the natural resources for their living. Land is the basic natural resource that provides habitat for terrestrial populations. It also provides space and opportunities for livelihood systems. On the other hand, people in many ways over-exploit land and water resources. Moreover, agricultural crop lands are being converted to brick fields, housing and for fish ponds that put pressure on cereal production and make the country unsecured in food grain production.

Fisheries sector plays an important role in Bangladesh through providing animal protein, employment and foreign exchange earning to the national economy. This sector presently contributes 4.43% of gross domestic product (GDP) and about 2.73% of total export earnings. The production of fish was 3.06 million MT [3].

Land use patterns are changing all the time with the growing population. In 1974-75, 59% land was under crop cultivation, 19% for forest, 2% for cultivable waste, nearly 4% for fallow, and 16% was not available for cultivation [2]. Thus, for the survival of Bangladesh's dense population, it is essential to have environmental planning that conserves and sustains the ecosystems that support them.

Therefore, understanding the changing pattern of land use has long been a major focus of research in land use planning. Space-born remote sensing (RS) has a good potential for change detection and good data availability and is consequently, well suited for the monitoring of land use change over a time period. The benefits of GIS application in aquaculture have promoted its quick expansion.

In the rural area, high productive lands are forcibly taken from the farmer by the industrialist. That's why the crop pattern and aquaculture are being changed. By conducting the land detection we can easily prevent people converting high productive aquaculture land to other uses. Integrated approaches or any alternative way are being developed by land use change detection. Fishery stocks are either exploited or over-exploited in many corners of the country.

The peoples are becoming dependent on the agriculture. That's why the aquaculture lands are being converted into agriculture. From the economic point of view, it is not a wise decision.

The study intends to land use change detection through RS and GIS for better aquaculture planning in trishal upazila to find out the land use changes during the last decades, find out the rate of land conversion to aquaculture uses and delineate high priority land for aquaculture based upon analyzing the images, GIS Tools and vegetation index model.

2. Materials and Methods

2.1 The Study Area

The study area Trishal Upazila is located in the northern part of the country near to Indian boarder Meghalaya in Mymensingh district which covers an area of 338.98 sq km. It lies between 24°35' and 24°58' north latitude and 90° 24' and 90°40' east longitude. The Old Bhramaputra river pass through the area and other rivers are Khiru, Sutia, Meduari, Nageshwari, Pagria and Barera; lots of notable depressions are present in the study area (Figure 1)

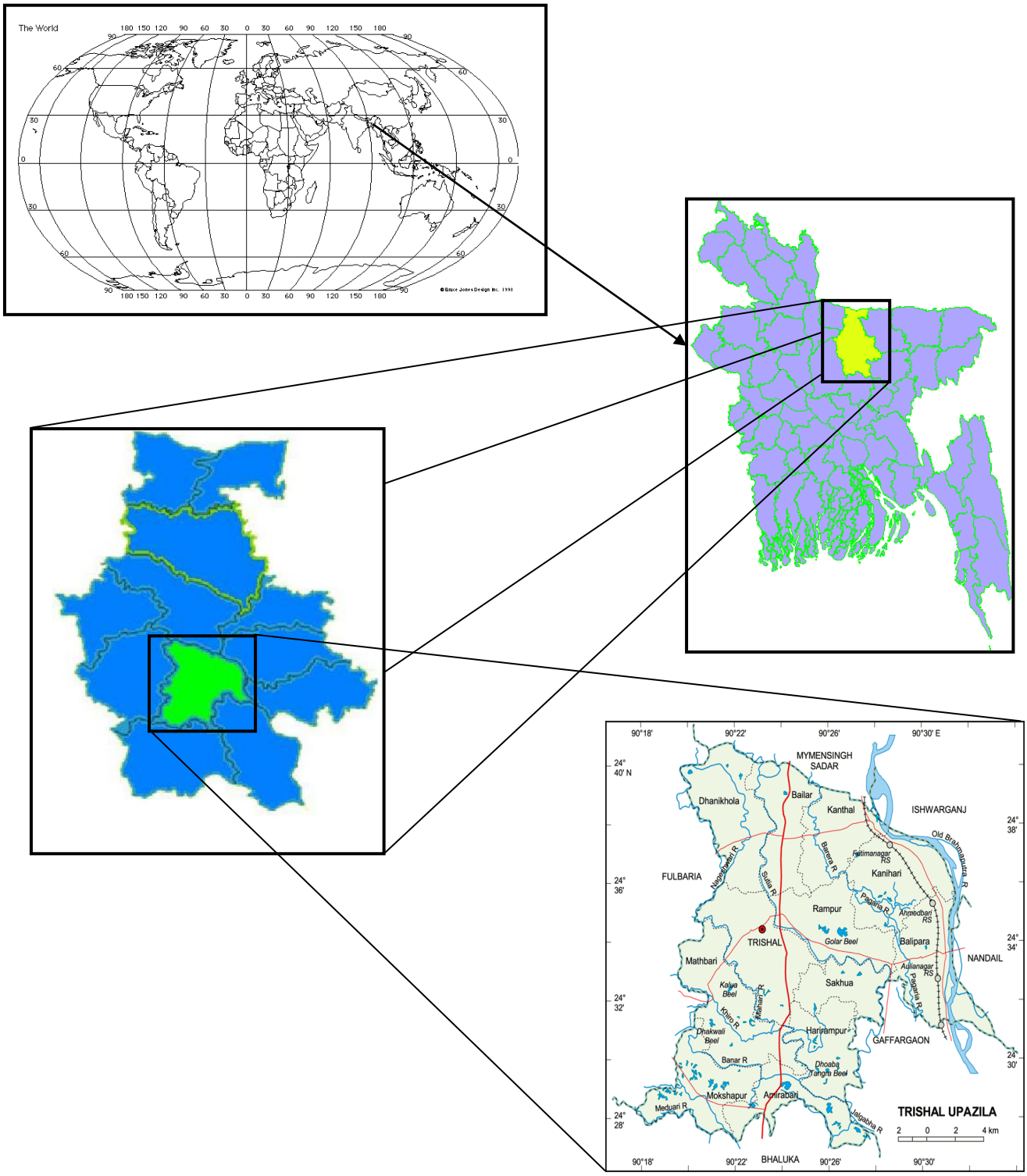

Fig 1: The map showing the study area; Trishal Upazila, Bangladesh

The weather patterns in the area governed mostly by the Southwest and the Northwest monsoon. The dry winter season starts from December to February when rainfall is infrequent, the climate of the area is warm and humid; but moderately cold and dry weather prevails in winter. The rainy season begins from mid April and continues till mid of September; while winter begins from the 1st of November and continues till mid of March. The humidity gradually decreases during this season. The sky remains generally clear.

2.2 Hardware, Software and image enhancement

The hardware components used in this study include units that are common to any computerized database management system. The GIS software IDRISI KILIMANJARO used in the study, developed by the Graduate school of Geography at Clark University, Worcester, MA, USA. The Microsoft Excel used for data analysis and trimming before being imported into IDRISI.

The Google images of 2000 and Landsat TM. Images of 1999 were used in the study, which supported by hard copy maps of the Local Government Engineering Department (LGED) and supported by secondary data collected from various sources, field visit and consultation with the relevant stakeholders.

2.3 Image Analysis Technique

The image enhancements with 5% stretch done for clear visual discrimination of vegetation, water and water-bare land boundary [4]. The overall image processing methodology for this study is presented in Figure 2.

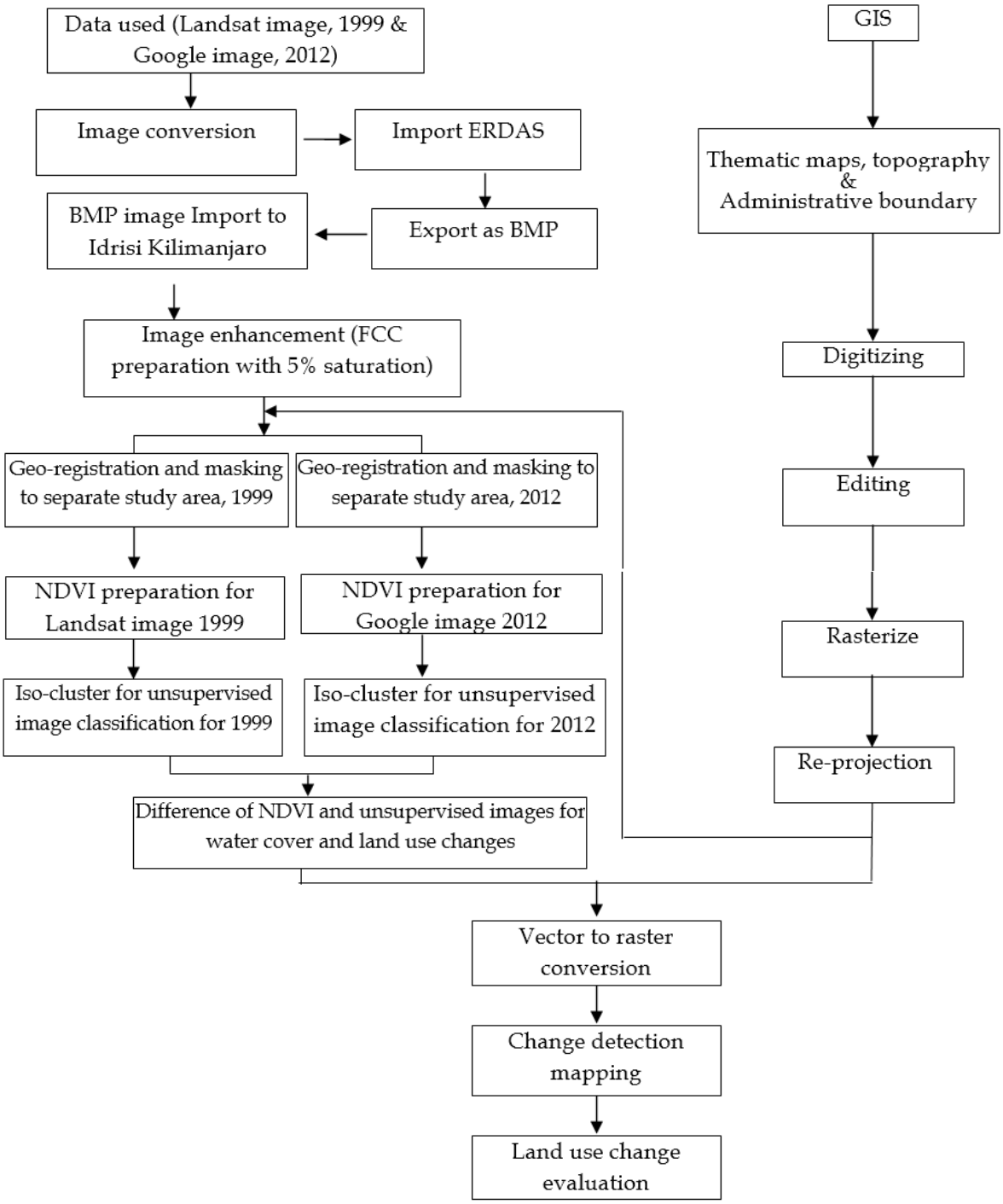

Fig 2: Schematic diagram of research methodology adopted in the study

2.4 Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) [7] applied to calculate the state of vegetation on the land surface with RED and mid infrared (MIR) bands of the satellite data through equation 1. Dense vegetation appears strongly in NDVI image, and areas with little or no vegetation are also clearly visible. NDVI technique is successful to identify water and bare lands clearly. It took values between -1 to 1, the value 0.5 indicates dense vegetation and value <0 indicates no vegetation. Produced NDVI image later reclassified in to five land use categories depending on the digital number (DN) as water, bare land, low vegetation, moderate vegetation and high vegetation types.

$$NDVI = \frac{MIR - Red}{MIR + Red} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, MIR is the digital number in the mid infrared band and RED is the digital number in the red band in Landsat TM and Google images. Table 1 describes the details of the data downloaded and used in the study.

Table 1: Landsat TM/Google image information used in the study

Image Data	Year of satellite over pass	Season
Landsat TM	1999	Late winter
Google Image	2012	Post monsoon

2.5 Unsupervised image classification

This module groups the features together with similar reflectance patterns. The module usually applied in the unsupervised image classification.

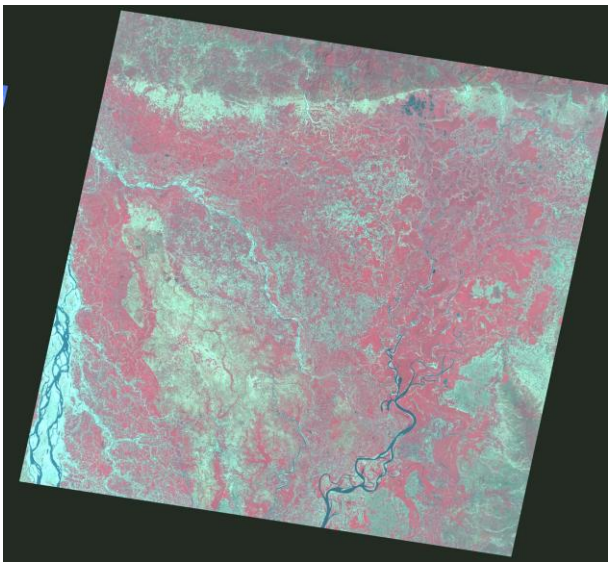

Fig 3: Landsat thematic image of Northwestern Bangladesh in 1999

The logic by which unsupervised classification works are known as cluster analysis and this provided in IDRISI KILIMANJARO by the ISOCLUSTER classification from the image bands of infrared, mid infrared and near infrared, and this provides an interpretation of spectral number in the raw data. This is done in several steps. Iso-cluster used with the option of user selected number of classes for the final image. The module then classified the images into discrete categories. This process was first conducted with 15 fine clusters which then finally classified into five classes. Following the fine cluster and reclassification, a 3 x 3 mode FILTER was carried out to eliminate all the small clusters less than 9 pixels. Figure 3 and 4 shows the Landsat thematic image 1999 and Google image 2012.

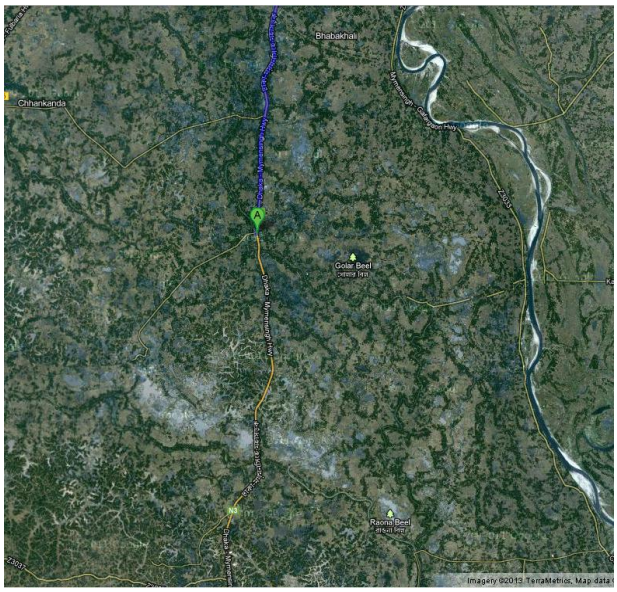

Fig 4: Google image of Mymensingh region in 2012

2.6 Data analysis

All the collected data were input into Microsoft Excel first and after sorting out it imported to KILIMANJARO GIS software and image analysis done. After image analysis, area calculation and cross tabulation done in GIS environment and exported into Excel again. The data refurbish in excel, graphical and tabular output done in Excel for report writing.

3. Results

3.1 False Colour Composite (FCC) analysis

To guide the land use change and land cover classification and NDVI image interpretation, FCC with blue (B), NIR and MIR bands for the year 1999 was obtained (Figure 5).

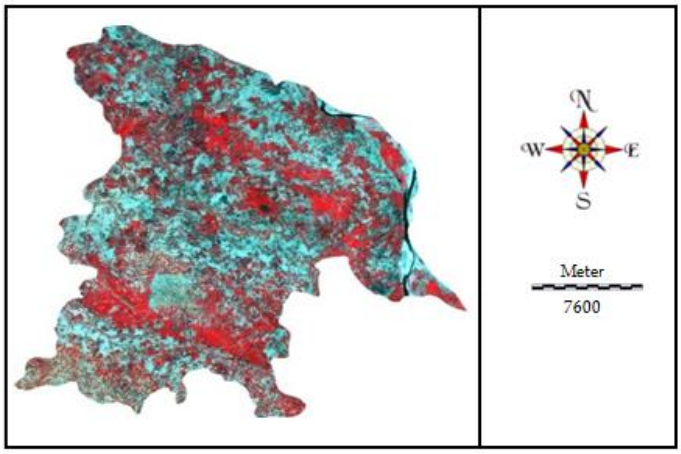

Fig 5: FCC image of Trishal Upazilla in 1999

In the FCC image of 1999, blue, blackish and purple colour represented water. Meanwhile, the blackish, blue and purple colour in FCC image is indicated turbid or shallow water. The red colour represented the trees and other greeneries in the images. Figure 5 showed FCC image of Trishal Upazilla of Landsat image in 1999.

3.2 Normalized Difference Vegetation Index

Normalized difference vegetation index map of Trishal upazilla was produced (Figure 6) where the Light colour showed the high vegetation and deep colour showed the low vegetation which indicated the vegetation, bare land and water area, respectively in the maps. The NDVI image interpretation showed that water and vegetation area were higher in 2012 image than the 1999 image. It was observed that comparatively higher water area present in 2012 image when compared with same image of 1999 but higher vegetation in 1999 than 2012. The NDVI images were reclassified into four land use categories.

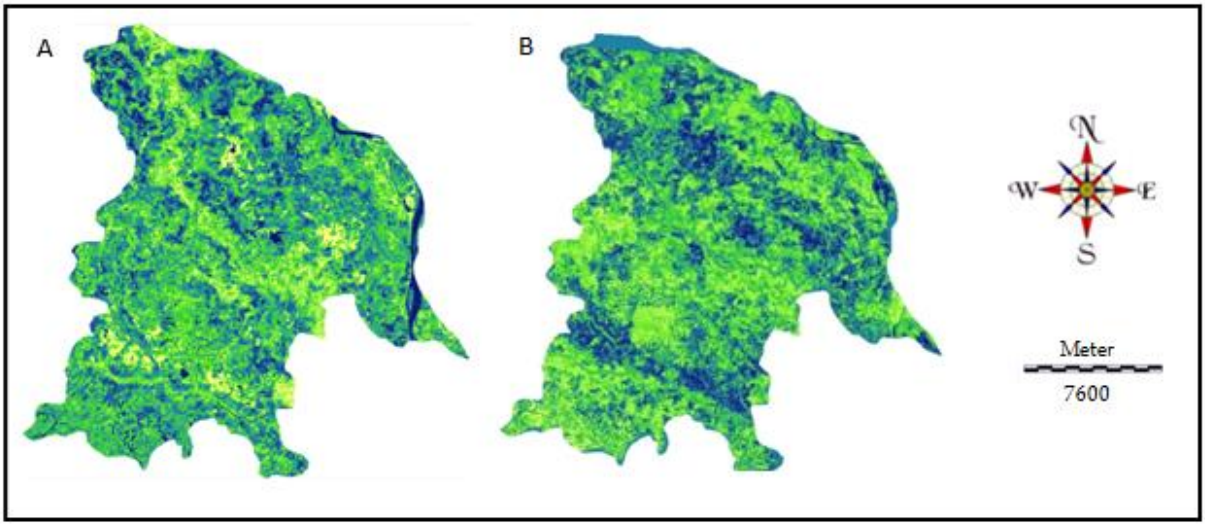

Fig 6: NDVI of Landsat TM image in 1999 (A) and NDVI of Google image in 2012 (B) in Trishal Upazilla, Northeastern Bangladesh

3.3 Unsupervised image analysis

The unsupervised image was produced through cluster analysis (Figure 7, 8) where different colour indicated water, field crops, homestead vegetation, bare land and water area in 1999 and 2012. Comparatively more water area observed in 2012 than in 1999. The land use types differed significantly ($P<0.05$) one another in different land use types. The water area was higher in 2012 image than in 1999 image due most of the natural water body dried up, silted or encroached by the farmers for crop cultivation or other purposes.

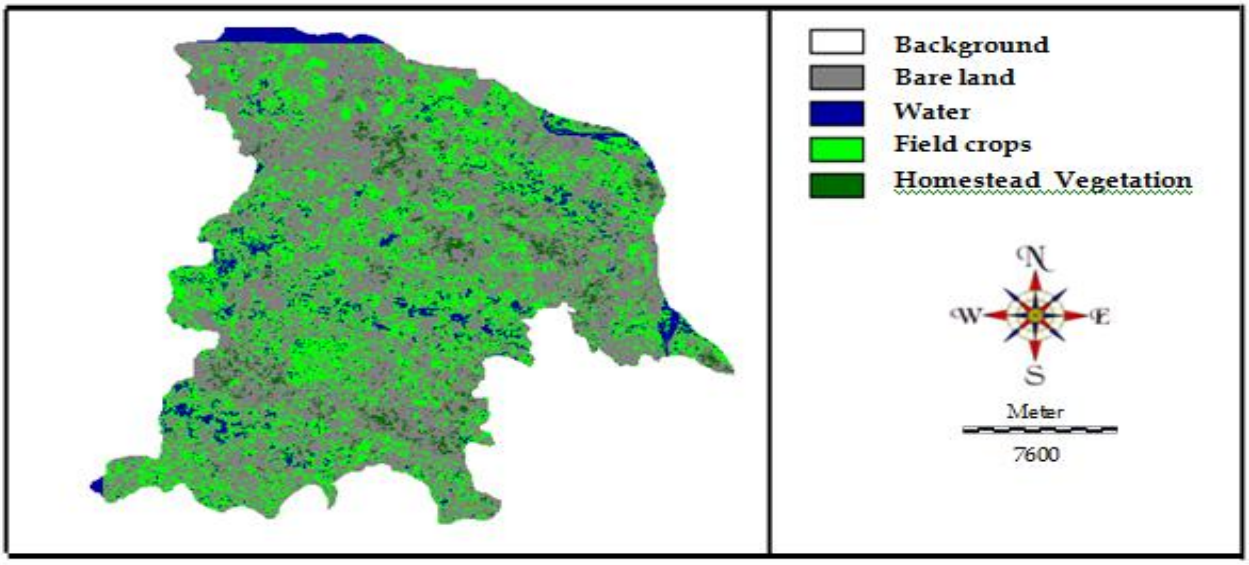

Fig 7: Trishal TM Unsupervised image in 1999

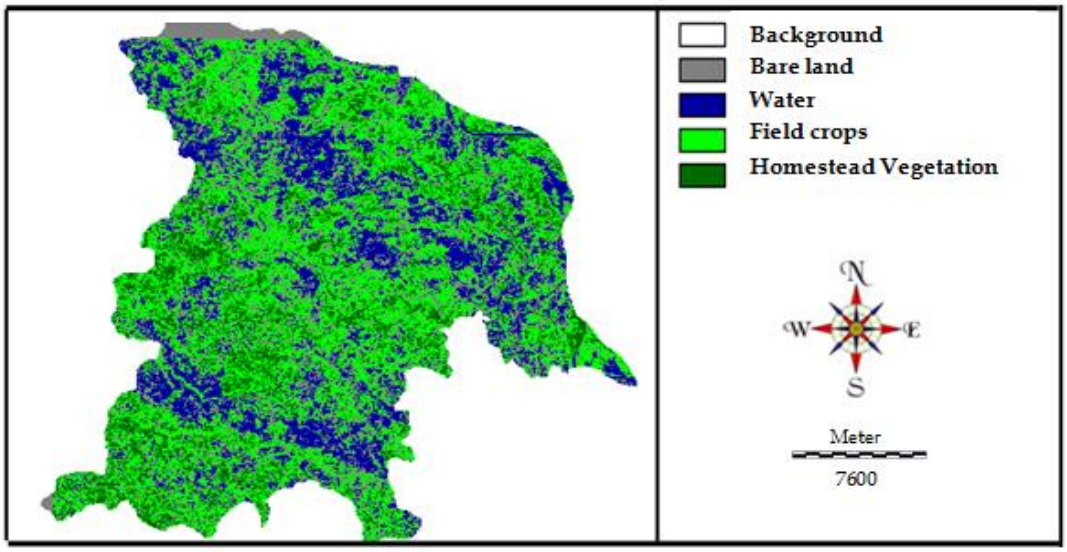

Fig 8: Trishal TM Google image in 2012

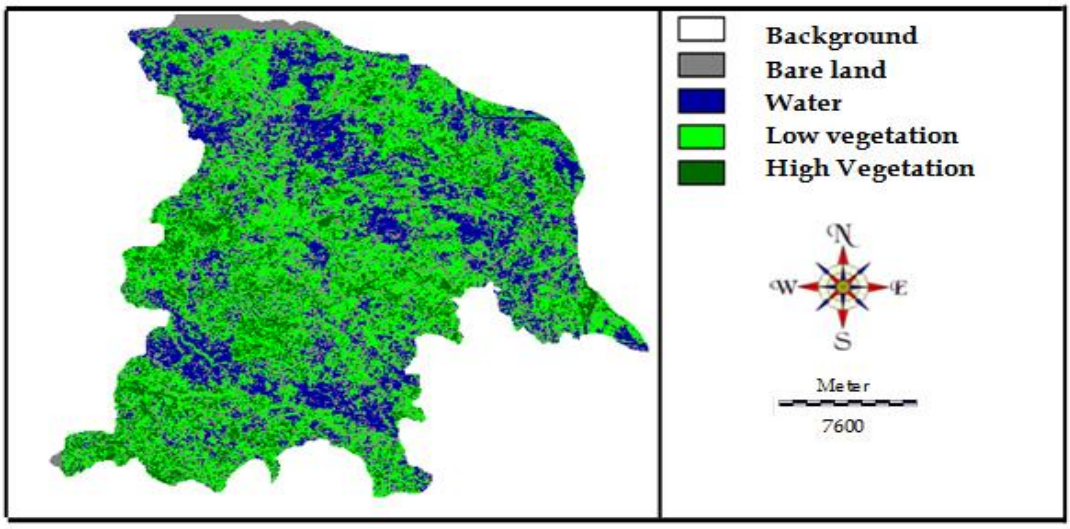

Fig 9: Trishal TM NDVI Image in 1999

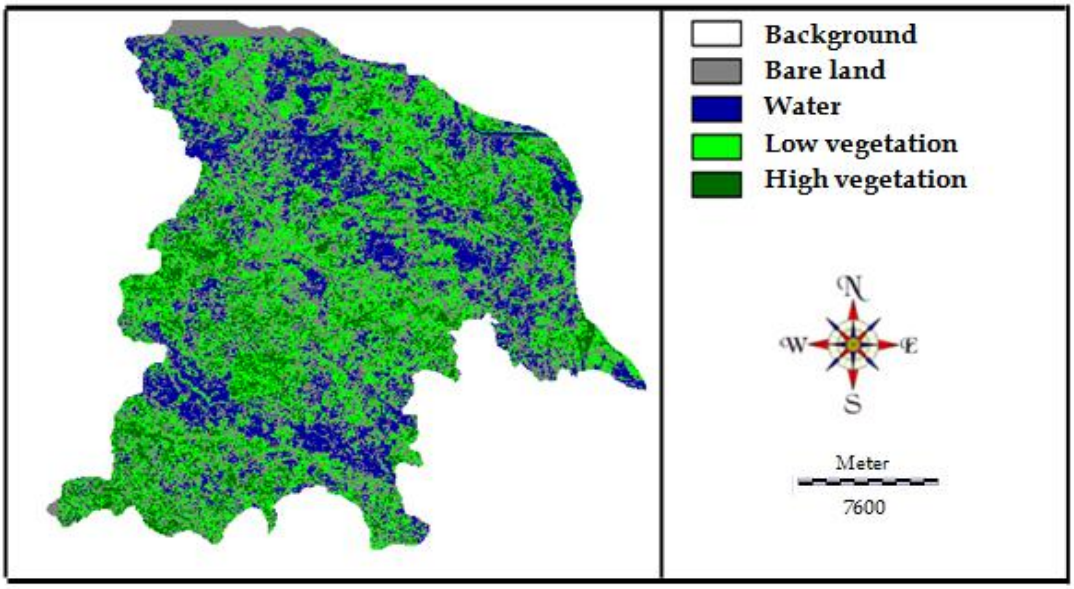

Fig 10: Trishal TM NDVI Image In 2012

3.4 NDVI Image analysis

The NDVI image of Trishal was produced (Figure 9 & 10) where different colour indicated water, bare land, high vegetation, low vegetation in 1999 and 2012. Huge vegetation was observed in both 1999 and 2012 images. Comparatively low vegetation area was observed in 2012 than in 1999. In the 1999 and 2012 images, the high vegetation area was more or less similar.

3.5 Unsupervised image reclassification

Unsupervised images were later on reclassified into land and water area for better understanding the land use in Trishal Upazilla (Figure 11 & 12) where 19% more water area observed in the year 2012 than in 1999.

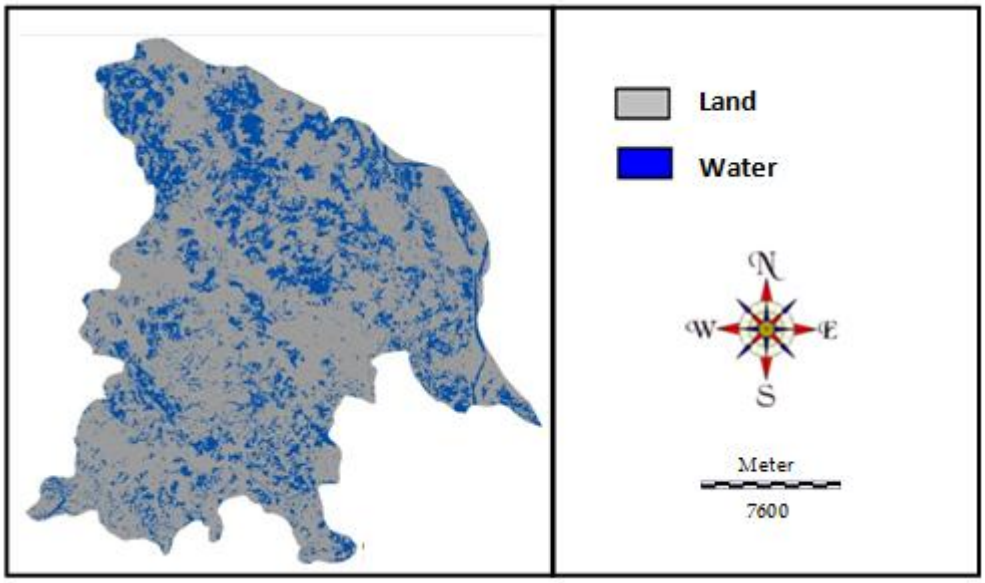

Fig 11: Unsupervised image reclassified to land and water in Trishal Upazila of Northeastern region, Bangladesh in 1999

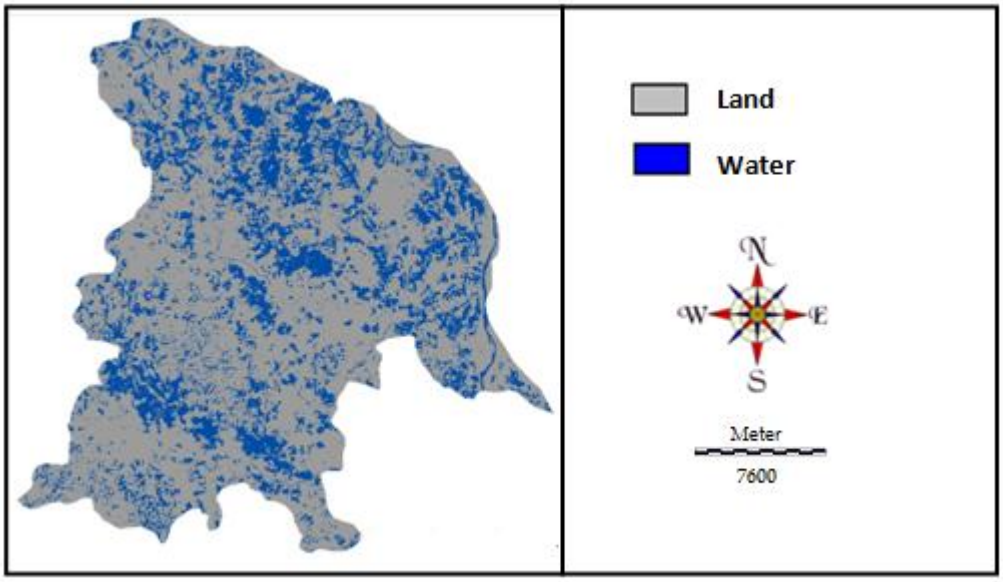

Fig 12: Unsupervised image reclassified to land and water of Trishal Upazila of Northeastern region, Bangladesh in 2012

3.6 NDVI image reclassification

The NDVI images were reclassified into two land use categories (Figure 13 & 14) and total area was calculated to compare the land and water areas in the respective images. The NDVI images interpretation showed that 2% more water area was observed in the year 2012 than in 1999.

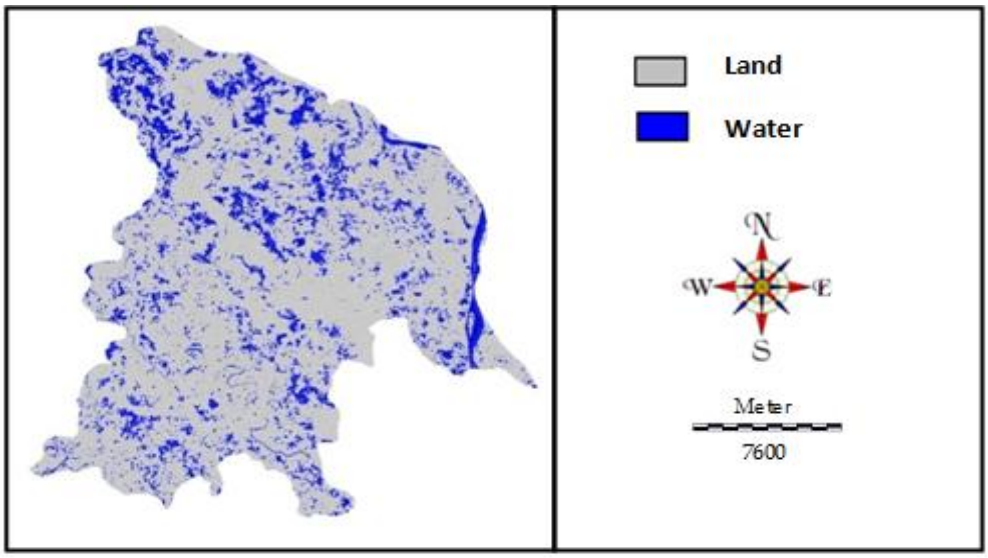

Fig 13: NDVI image reclassified to land and water of Trishal Upazila of northeastern region, Bangladesh in 1999

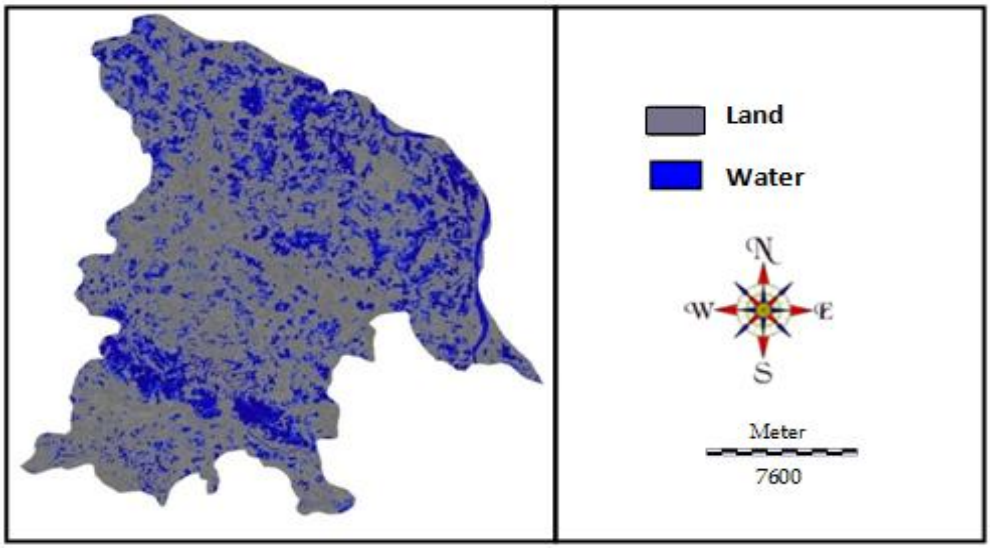

Fig 14: NDVI image reclassified to land and water of Trishal Upazila of northeastern region, Bangladesh in 2012

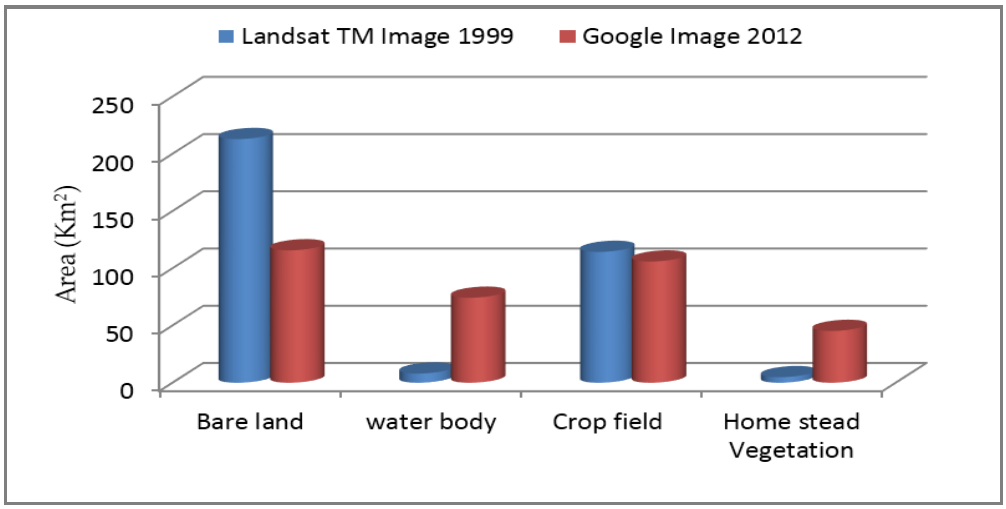

Fig 15: Comparison of total area of Unsupervised Landsat image (1999) and Google image (2012) in Trishal Upazila

3.7 Total Area Calculation

The area in two different images was analyzed. The water area differed significantly ($P<0.05$) in different years. However, an increasing trend observed in the images of 1999 to 2012. The water area was comparatively 21% higher in the year 2012.

The total area as per NDVI and unsupervised analysis were presented. It is observed in both cases that the water area of Google image of 2012 is higher than Landsat TM images of 1999 due to increasing number of fish ponds during the period have been constructed.

The unsupervised image comparison has shown that, the bare land in Landsat image is much higher in comparison with the Google image because the huge area of bare land in the image, as the water is not so high in the Landsat image which has shown in the category. The condition of field crops was good in comparison of homestead vegetation. In the year 1999, the water availability was not good, that's why the amount of homestead vegetation was not good enough. In the year 2012, the bare land has decreased due to the water body which also increased the field crops and homestead vegetation. (Figure 15)

In the NDVI image analysis, it was the aim to observe the total vegetation in the land. In the year 1999, the vegetation level was similar to the bare land, but in the year 2012, the high and low vegetation both has increased a bit. The water body was also increased in comparison with the Landsat image due to increased ponds in this time. These increased water bodies have been constructed during the last decade to culture pangus, tilapia and other fish in the area. This is a good sign, but we have to be careful to convert the land to fish pond. We can only convert the land to ponds which are fallow or only one crop is cultivated. Moreover, if conversion is necessary, then integration with other crops is needed. Also, as water is available round the year in the area, hence, the vegetation also has increased in the region. (Figure 16)

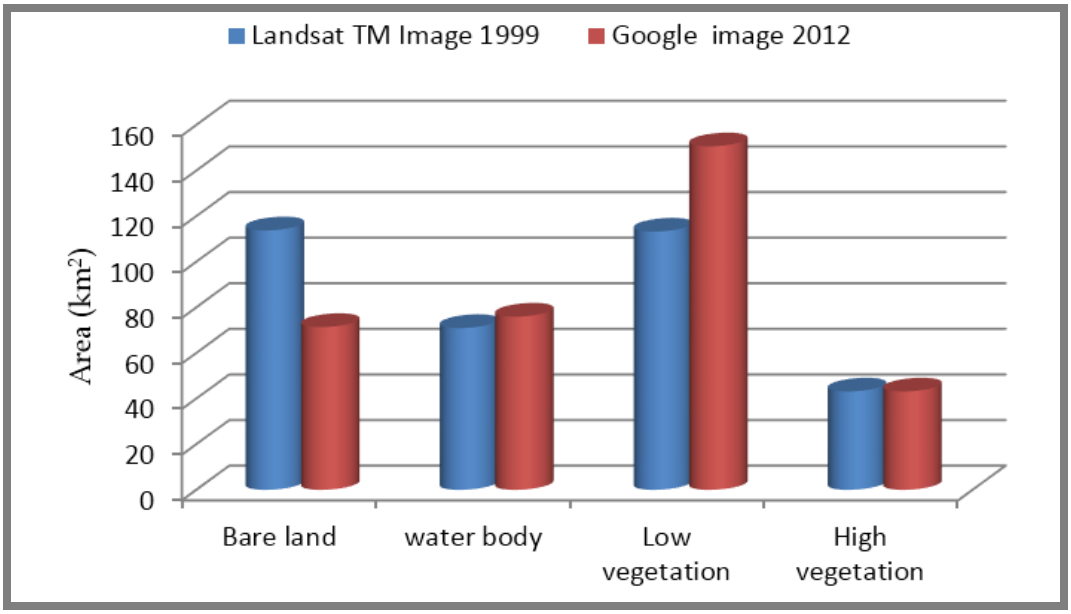

Fig 16: Comparison of total area in NDVI Landsat image (1999) and Google image (2012) in Trishal Upazila, Bangladesh

4. Discussion

The False Colour Composite (FCC) images of blue (B), near infra-red (NIR) and mid infra-red (MIR) bands for the year 1999 and 2012 were obtained to guide the land use and land cover classification and NDVI images interpretation. The FCC of two same seasons of two years were different which could be differences in reflectance due to change in crop growth stages plus changes in atmospheric and soil moisture conditions [6].

Detailed FCC and the NDVI images interpretation showed that the water areas were higher in 2012 Google image than a Landsat TM image of 1999. In the area calculation, it is shown that, in the NDVI image of 1999, the water area was 70.97 km^2, but in the year 2012, it increased upto 75.98 km^2, which means the increase rate of water is 2%. Aquaculture planning can be easily done in that place. The cause of increasing the water is the decrease rate of bare land in the same area. The Nana Kosi watershed has a period of moisture surplus from the rainy season and the remaining months are a period of deficit through a study using remote sensing images and GIS approach which supports the present finding [5].

Finally, it was clear from the study that there was huge land use change over the time in the region. Bare land was higher in 1999 and less water area in the area. The total cultivable land was 126 km^2 in the Landsat image of 1999, which increase up to 224 km^2 in the Google image of 2012, which indicate that there is a huge land use change which can be useful for aquaculture. In the NDVI image of 1999, the total vegetation was 156.41 $km^{2,}$ which increase up to 193.79 km^2 in the Google image of 2012. In percentage the total area is increased up to 10%. Whereas, water area has increased quite a lot over the year that means rice fields or other agricultural fields have converted to fish ponds. This area can be used for fish culture by which we can as an opportunity, but we have to careful to convert rice fields to fish ponds as we need rice to feed the countrymen as well. There are 22% area were suitable for aquaculture in Mymensingh district. These findings support the present finding [1].

In the extended 66 km^2 areas, we can culture fish without spending a penny for water installation. Therefore, fish species which are first growing and become harvestable size in a short period like tilapia, SIS, shingh, magur, koi, etc. can culture. On the other hand, by using balanced feed and environmental management different carp species can be cultured in this area all the year round. In this way, we can utilize these water areas properly without any interruption.

5. Acknowledgements
The authors gratefully acknowledge with gratitude to the Department of Aquaculture, Bangladesh Agricultural University, Mymensingh, Bangladesh for providing the facility to carry out this research work and the contribution of the National Science and Technology Fellowship for funding the research work.

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