USE OF MULTIPLE SATELLITE IMAGES IN MULTIPLE SCALES FOR FEATURE EXTRACTION AND IMAGE CLASSIFICATION: A CASE STUDY OF RAMSAR WETLAND IN NORTH EAST INDIA

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Abstract: Several techniques are being used for extracting information from satellite images from decades. Extracting features based on segmented objects of the image is relatively a newer and efficient approach. However, for heterogeneous areas with high variations of Land Use-Land Cover (LULC) it is difficult to obtain accurate classified map from moderate resolution image like Landsat 4-7. Deepor Beel, a Ramsar wetland and its catchment in North East India is an example which consist of various topographical and LULC variations. In this study, a rule based classification algorithm was developed using spectral and spatial information of Landsat using ASTER DEM and band ratios such as NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), band2/band5, band5/band7 etc. as the ancillary information. The classification was done in two different scales: extended catchment scale and wetland scale. For catchment scale, the hilly forests could be easily separated from plain forests due to the use of the DEM. The water indices helped to accurately differentiate between water logged areas and urban areas. The validation using field data proved an accuracy of 94% and kappa coefficient of 0.91in case of the extended catchment scale classification. Using the classified datasets, the cover types dynamic degree change has been evaluated from 1989 to 2011.

INTRODUCTION

Wetlands and water bodies are among the World's most productive environments, but in most part of the world they are threatened due to immense pressure from human activities combined with climatic disturbances (An et al. 2007; Erwin 2008; Prasad et al. 2002; Han et al. 2012). India has totally 67,429 wetlands, covering an area of about 4.1 million hectares out of which, 2,175 are natural and 65,254, man-made (MoEF, 1990). In the Indian subcontinent, due to rice culture there is a vast loss in the spatial extent of wetlands. Due to the suitability of the soil, rice farming is a wetland dependent activity and is developed in riparian zones, river deltas and floodplains. Also, due to the capture of precipitation and runoff in the upstream zones for rice farming and fish culture, water is deprived to the downstream natural wetlands. Of the estimated 58.2 million hectares of wetlands in India, 40.9 million hectares are under rice cultivation (Prasad et al. 2002).

There have been numerous efforts for extraction of meaningful information related to wetlands from satellite images (Baker et al., 2006; De Roeck et al., 2008; Grenier et al., 2007). There have been a number of satellite images which have been used in wetland studies such as Landsat (TM, ETM), IRS (LISS), Envisat, Radar, Lidar etc (De Roeck et al., 2008; O'Hara, 2002; Ozesmi and Bauer, 2002).

Deepor Beel, located about 10 km southwest of Guwahati city, Assam, India is considered as one of the large and important riverine wetlands in the Brahmaputra valley of lower Assam (figure 1). It is surrounded by the Bharalu basin in the east, the Kalamani in the west, Jalukbari in the north and Rani and Garbhanga reserve forests in the south. It lies between 91º35′ to 91 º 43′ E longitudes and 26º05′ to 26º11′N latitude. It is recognized as one of the most significant wetland systems (10,000 acres) in the world under the Ramsar International Convention on Wetlands.

In this study an attempt has been made to study the Ramsar wetland and its upland in multi scale from multiple remote sensing satellite images. A number of water indices and band ratios have been used to classify the image into meaningful classes related to the wetland study.

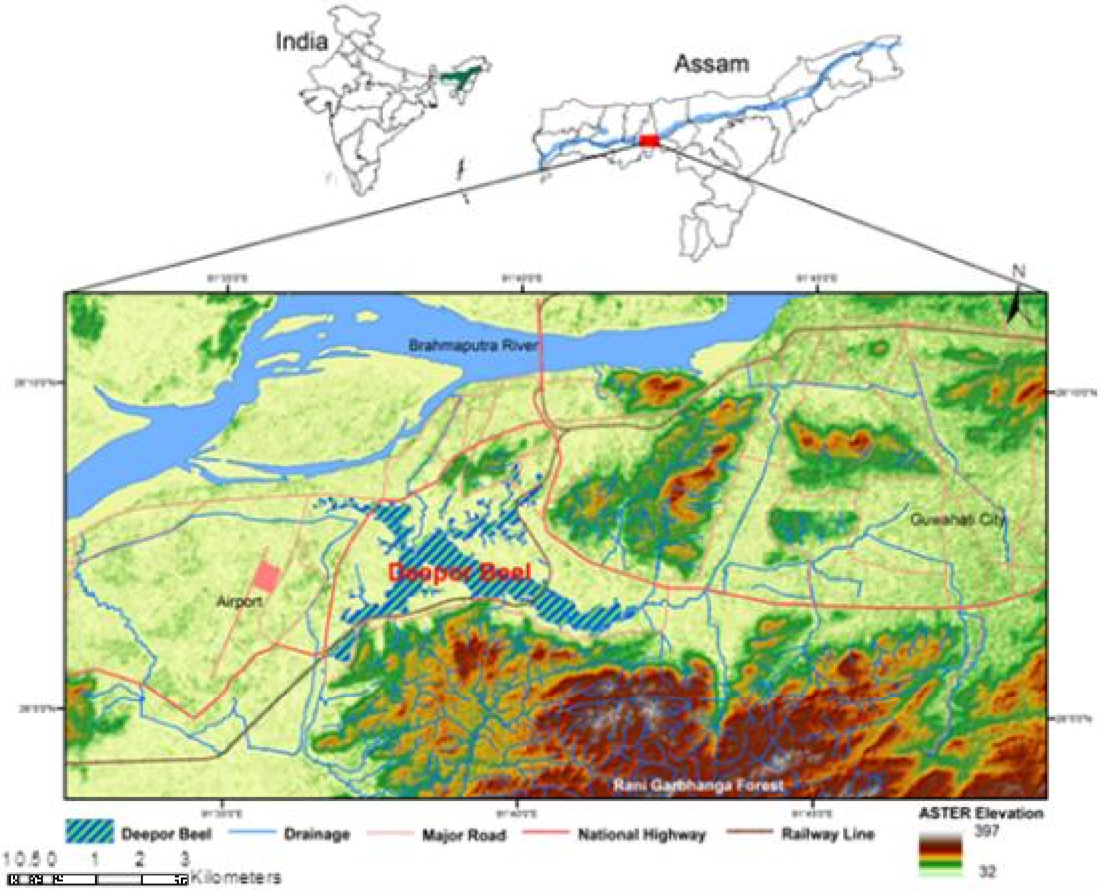

Figure 1: Location map of study area

METHODS AND EQUATION

Data

The Landsat (TM, ETM+) multi temporal data of 12th January 1989, 3rd June, 25th October, 26th November 2000, 29th January, 2nd March, 3rd April, 8th July, 28th October 2001,1st February 2002 and 9th January 2011 (hereafter Jan 1989, Jun 2000, Oct 2000 etc.) were used for the historical and seasonal wetland change analysis. The DN values of the images were converted to radiance based on a calibration curve of DN (Chander and Markham, 2003; Negi et al., 2009). The radiance were simulated to reflectance values using 6s (Second Simulation of a Satellite Signal in the Solar Spectrum) radiative transfer code (Vermote et al., 2006).

The ASTER obtained elevation data with 30 m spatial resolution was used which have estimated accuracies of 20 meters at 95 % confidence for vertical data and 30 meters at 95 % confidence for horizontal data (ASTER, 2009). The DEM was reconditioned using ancillary drainage maps prior to prepare the slope maps using ARC Hydro Tools in ARC GIS 10.

Wetland Detection and Masking

For the historic wetland change analysis, it was required to differentiate and determine wetland boundary as no proper Deepor Beel boundary could be found from the administration. Several water indices have been derived from arithmetic operation of two bands of the satellite which also diminishes the noise components of the wavelength (Table 1). NDVI stands for Normalised Difference Vegetation Index, NDWI stands for Normalised Difference Water Index, MNDWI for Modified NDWI, NDPI for Normalised Difference Pond Index and NIR, R, SWIR, Green are the reflectance values of Landsat satellite. Region of Interest (ROI) was created by thresholding using the unique threshold values of indices in ENVI 4.7.

Image Classification

This study comprised of classification in 2 different scales: extended Catchment scale and Wetland scale to study the change in cover types within and around the wetland. Since the attempt was made to use rule based classification from Landsat images, we used several bands and band ratios apart from those mentioned in the table 1. The study basin consists of hilly areas which leave shadow on the images. One major challenge was that the classification scheme developed here, over classified many of these shadow regions as water logged areas. To overcome this, the slope layer prepared from DEM was included to the ruleset with a value of Slope ≤ 5 °. The catchment scale and wetland scale classification classes and inputs are shown in table 2 and 3.

Table 1: Indices used in the study

Index	Formula	Values Range	Sources
NDVI	(NIR - R)/(NIR + R)	-1 to +1	Rouse et al., (1973)
NDWI (1)	(NIR - SWIR)/(NIR + SWIR)	-1 to +1	Gao (1996)
NDWI (2)	(Green - NIR)/(Green + NIR)	-1 to +1	McFeeters (1996)
MNDWI	(Green - SWIR)/(Green + SWIR)	-1 to +1	Xu (2006)
NDPI	(SWIR - Green)/(SWIR+ Green)	-1 to +1	Lacaux et al. (2006)
NDTI	(R - Green)/(R + Green)	-1 to +1	Lacaux et al. (2006)

Table 2: Classification inputs for rule based classification in extended Catchment scale

Cover type	Inputs used for Classification
Water	NDPI < -0.4 AND ELEVATION < 80.0000 AND SLOPE < 5 OR NDVI < 0.04 OR Green/SWIR1 > 1.3 AND ELEVATION < 80 AND SLOPE < 5
Sand bar	SWIR/NIR > 0.87 AND Green > 0.18
Dense Vegetated Hill	NDVI > 0.6 AND ELEVATION [80, 632.2]
Medium Dense Vegetated Hill	NDVI [0.45, 0.6] AND ELEVATION > 80
Light Dense Vegetated Hill	NDVI [0.25, 0.45] AND ELEVATION > 75 OR SWIR2 < 0.15 AND ELEVATION > 75 AND NDVI < 0.45
High Dense Vegetation	NDVI > 0.6 AND ELEVATION < 80
Medium Dense vegetation	NDVI [0.45, 0.6] AND ELEVATION < 80
Light Dense Vegetation	NDVI [0.3, 0.45] AND ELEVATION < 80
Crop land	NDVI > 0.28 AND SWIR1 > 0.22 AND Green < 0.18
Fallow Land	NDVI < 0.28 AND SWIR1 > 0.22 AND Green < 0.18
Water Logged Area	NDPI [-0.4, -0.15] AND ELEVATION < 70 AND NDVI < 0.3 OR MNDWI [0.08, 0.35] AND NDVI < 0.3 AND ELEVATION < 70 OR NDWI(2) < -0.24 AND NDVI < 0.3 AND ELEVATION < 70
Built up	NDWI(2) > -0.24 AND Green < 0.18 AND NDPI > -0.1 AND SWIR1 < 0.22 AND MNDWI [-0.21, 0.08] AND NDVI < 0.5 OR NDVI < 0.5 AND NDPI > -0.1 AND SWIR1 < 0.2 AND MNDWI < -0.11

Table 3: Classification inputs for rule based classification in Wetland scale

Classes	Description	Rule
Open water	Exposed clear water surface: high water indices, very low NDVI	(NDVI <0.1 AND NDWI1 <-0.5) OR (NDVI <0.1 AND MNDWI >0.3) OR (NDVI <0.1 AND NDPI <-0.5)
Transition zone	Water with slightly vegetated or suspended material other than vegetation: high water indices, low NDVI	(0.1 <NDVI <0.3 AND NDWI1< -0.5) OR (0.1 <NDVI <0.2 AND MNDWI >0.3) OR (0.1 <NDVI <0.2 AND NDPI < -0.5)
Aquatic Macrophyte	Water with vegetated cover including floating and emergent vegetation: high water indices, medium to high NDVI	(NDVI >0.3 AND NDPI <-0.5)

Mudflat	Cover type exposed with soft waterlogged area, slightly vegetated and/or thin sheet of water: medium water indices, low NDVI	(NDVI <0.3 AND -0.5 < NDWI1< -0.25) OR (NDVI <0.3 AND 0< MNDWI <0.3) OR (NDVI <0.3 AND --0.5 < NDPI < -0.15)
Low Vegetated moist land	Sparse vegetated areas within wetland including short grassland and agriculture lands: Low water indices, medium NDVI	(0.3 < NDVI <0.5 AND -0.5 < NDWI1< -0.25) OR (NDVI <0.3 AND 0< MNDWI <0.3) OR (NDVI <0.3 AND --0.5 < NDPI < -0.15)
High Vegetated moist land	Highly vegetated areas within wetland including grassland and bush lands: Low water indices, high NDVI	(NDVI >0.5 AND -0.5 < NDWI1< -0.25) OR (NDVI <0.3 AND 0< MNDWI <0.3) OR (NDVI <0.3 AND --0.5 < NDPI < -0.15)

Accuracy Assessment

Sixty Ground Control Points (GCPs) were collected from the catchment of the wetland during the same period of classification image. The accuracy assessment was done with error matrix with producer's and user's accuracy. The Kappa coefficient was used as the measure of overall accuracy. However, this accuracy assessment was done only for catchment scale and could not be done for the wetland scale.

Change Detection

Along with a cross tabulation method for the cover types change detection, to determine the change rate of land use categories over the study periods, the land use dynamic degree ($LUDD_{single}$) was used. The computational equation given by

$$LUDD_{single} = \frac{U_b - U_a}{U_a \times T} \times 100\% \quad (1)$$

Where, U_b and U_a are the area of cover type in time b and a respectively, T is the interval between b and a.

RESULTS

Accuracy Assessment

Hundred percent Producer's accuracy and User's accuracy was obtained for Water, Sand Bar, Built up and Fallow land. Producer's accuracy was 100 % also for light dense vegetated hill and other light dense vegetation. For high dense vegetated hill and crop land, the user's accuracy was 100 %. The overall accuracy was found as 93.46% and kappa coefficient was 0.91.

Historical Change in Deepor Beel Catchment Scale

Figure 2(a) shows the classified map of Deepor Beel and its upland in the extended catchment scale. Figure 3 (a) shows the dynamic degree change of Deepor Beel on the catchment scale. The 3 period data shows the transition from 1989 to 2001, 2001 to 2011 and the overall change from 1989 to 2011. The highest overall change has been observed in case of Light dense vegetated Hills which aggravated due to conversion from High Dense Vegetated Hills i.e., the forests which indicates the deforestation in the catchment. Overall, the Built up also has been aggravated. However, the built up increase from 2001 to 2011 is negligible compared to increase from 1989 to 2001. Interestingly, the fallow lands in the area shows a huge increment from 1989 to 2001 in spite of same season data, however, the overall change from 1989 to 2011 was almost negligible.

Historical Change in Deepor Beel Wetland Scale

Figure 2 (b) and 3 (b) shows the classified map in 2011and dynamic rate of change of the cover types in each study period. Open water and mudflat decreased; grassland, light vegetated land and transition zone increased at a low speed, whereas aquatic macrophyte increased at a very high speed. For aquatic macrophytes, the change trend accelerated continuously with a very high rate of 36.6% from Jan01 to Jan11. Open water rather decreased at a nearly constant speed with an average of 3.7%. The transition zone and light vegetated land accelerated during Jan89 o Jan01 which later decelerated in the period of Jan01-Jan11. The highest acceleration observed for grass land from Jan01 to Jan11 with a value of 80.8%, whereas the overall rate was decreasing trend and relatively quite low with value of 1.7%. Contrast to this, the mudflat degree of increase was 22% which reduced to 8% only in Jan01-Jan11 period. In addition, the water spread boundary increased from 948 ha in Jan89 to 1012 ha in Jan01 and then decreased to 990 ha in Jan11.

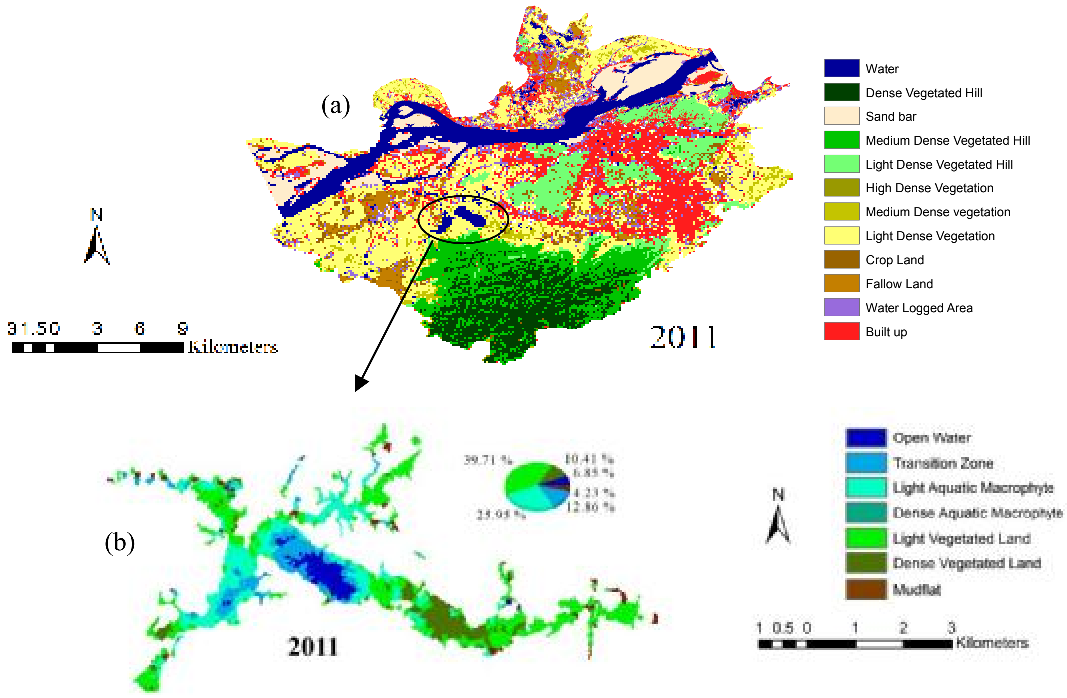

Figure 2: Rule based classified map for Deepor Beel in
(a) Extended Catchment Scale (b) Wetland Scale for Jan 2011

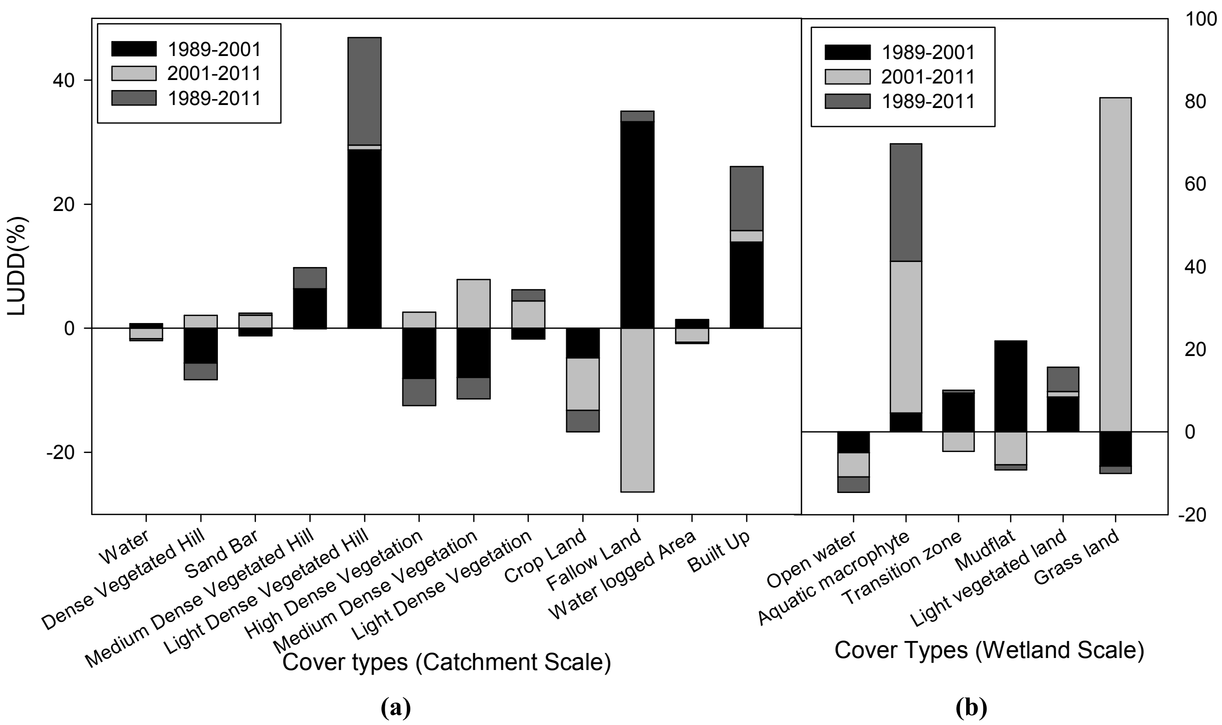

Figure 3: Cover type dynamic degree change for Deepor Beel in
(a) Extended Catchment Scale (b) Wetland Scale

DISCUSSION

The rule based classification using multiple satellite images result was compared to supervised (maximum likelihood) and recoded classified results from 2011 image. The accuracy increased from 85% in case of supervised to 94% in rule based classification. In addition, using rule based classification; the more number of classes could be differentiated than using supervised classification. The vegetated hills could not be accurately differentiated from other non-hill vegetation using supervised classification scheme. The use of DEM in rule based classification made it more accurate. Again, some water logged areas were found mixed with built up areas in case of supervised classification scheme. However, the 2 cover types could be more accurately differentiated by using the water indices as ancillary data in rule based classification.

The major changes in the catchment scale study area was observed to occur in the period 1989-2001, and in contrast the major changes in wetland scale has found to happen from 2001 to 2011. Also, the wetland scale changes were in terms of decrease in open water, increase in floating aquatic macrophyte and conversion from “wetland” to “grass land”. The increase in floating macrophytes during 2001-2011 leads to a case of eutrophication which might have resulted from the land conversion in the catchment during 1989-2001.

In addition, the water spread boundary increased from 948 ha in Jan89 to 1012 ha in Jan01 and then decreased to 990 ha in Jan11. This was little surprising since the average rainfall during 1988-89 was 187.8 mm whereas in 2000-01, this was 150.4 mm. It was difficult for us to find the reasons behind, since there is very limited printed information available for our study area. However, there was a major event during this period which is the construction of railway, started in 1992-93 and completed in 2001. We used the catchment scale classified maps of Deepor Beel and found that due to this construction, almost 1000 ha croplands were lost (data not shown here). This was also confirmed by the socio economic data of the surrounding villages in 2001 (OKD, 2001). There is a possibility of development of new croplands in the south east side of the wetland, since it was easy to irrigate their croplands from the wetland due to lower elevation. Also, 3548 ha of forest cover was lost during this period in the Rani Garbhanga forest which increased the siltation process in Deepor Beel. This might have attributed the water to flow to the lower elevated areas which increased the water spread boundary in Jan01.

CONCLUSIONS

In summary, we have explored different aspects of Deepor Beel, a Ramsar wetland by using smart sensing through space and a multi scale (catchment and wetland scale), multiple satellite image based classification using a number of ancillary data is described. The overall accuracy and Kappa statistics of the classified map in extended catchment scale was found to be 94% and 0.91. Using the rule based classification algorithm, almost 9% improvement in the overall accuracy was found as compared to that obtained from supervised classified map. The developed rules for catchment and wetland scale were applied to 1989, 2001 and 2011 images for the change detection of the wetland. The highest overall change for catchment scale was observed in case of medium dense vegetated hills, due to the deforestation as well as built up through urbanization. These changes in turn had an adverse effect on the cover types in wetland scale. This led to eutrophication and conversion of wetland to grass land during the period 1989-2011. This study is being continued and other factors of the changes in the wetland scale, such as hydro-geomorphological factors, topography, socio economic factors etc. are being considered as future study.

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