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Mapping of cropping pattern of East Kolkata Wetland Area using multi-temporal satellite data

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Abstract: East Kolkata Wetland Area, a Ramsar Site, got internationally recognized for ensuring ecological balance using a reliable traditional technology for wastewater treatment, and equally for bringing economic gains. This waste recycling region, which includes fishponds (locally called as 'bheris'), garbage farms and paddy lands, provides Kolkata city a low-cost alternative to wastewater utilisation, along with the supply of fresh vegetables and fish at cheaper rates. The present study applies composite NDVI classified mapping technique on multi-temporal satellite data for mapping the cropping pattern of this wetland area. The aim is to determine whether any change in cropping pattern and landuse has occurred since 2002, when it got internationally recognized, till 2010. The study reveals that between the said time periods there is an increase in double-cropped and horticulture regions, along with decrease in waterlogged wasteland. However, non-vegetated area has decreased suggesting a decline in wetland area due to the conversion of fishponds into other landcover classes.

Keywords: East Kolkata Wetlands, NDVI, Multi-temporal satellite data, Cropping Pattern

1. Introduction

Over the last few decades, remote sensing technology has established its potential in regional to global scale mapping and monitoring of land surface conditions. Its application in the study of vegetation dynamics has helped to estimate crop yield, pasture performance, rangeland carrying capacities, forest monitoring and provide early warning on droughts and famines among others (Gitas et al., 2012; Lenney et al., 1996; Michener and Houhoulis, 1997; Xiao et al., 2002).

Numerous vegetation indices (EVI- Environmental Vegetation Index; PVI- Perpendicular Vegetation Index; GNDVI – Green NDVI; EVI – Enhanced Vegetation Index (MODIS)) have been developed to conduct vegetative study from satellite imageries of various sensors (Bannari et al., 1995; Gobron et al., 2000). In other words, for regional to global scale vegetation study, the vegetation indices were applied on various coarse to medium spatial resolution sensor data, ranging from AVHRR, MODIS, Landsat MSS and Landsat TM (Gitas et al., 2012; Justice et al., 1991; Coppin and Bauer, 1994). Several time-series Normalised Difference Vegetation Index (NDVI) data analysis using remote sensor data have been conducted in past for analyzing the vegetation phenology and dynamics (Knight et al., 2006; Sakamoto et al., 2005). However, Normalised Difference Vegetation Index (NDVI), developed by Rouse et al. in 1974 (Ribeiro, 2012), remains the basic vegetation index most widely used for monitoring of vegetation (Purevdorj et al., 1998; Townshend and Justice, 1986). It has an advantage of cancelling out a large proportion of signal variations attributed to calibration, noise, and changing illumination conditions other than changing sun angles, topography, and other extraneous factors (Lillesand et al., 2004). NDVI is an indicator of the overall vegetation status of an area, including natural vegetation and agriculture.

The study area is about 125 sq km. Landsat TM data and ETM+ datasets have been used in the present study. A time series data analysis has been conducted to develop a composite NDVI classified map for vegetative study. The objective of this regional-scale study was to apply composite NDVI classified mapping technique on multi-temporal satellite data for cropping pattern and vegetation characterization of a Ramsar protected wetland area. In this study term 'vegetation' has been generalized for both crops and natural vegetation. With a simple but effective methodology based on the NDVI, multi-temporal Landsat-5 TM and Landsat-7 ETM + image data were classified and compared to assess the change in vegetation coverage over the years.

2. Background

Since NDVI exhibits a near-linear relationship with the fraction of photosynthetically active radiation absorbed by the vegetation canopy (fPAR) (Asrar et al., 1984) and net primary production (NPP) (Goward et al., 1985), thus, it is often used for study of vegetation. Remote sensor system's ability to identify vegetation classes is a result of wavelength specific pigment absorptions (0.45-0.69 μm), foliar reflectance (0.76-0.90 μm) and foliar moisture content (1.55-1.75 μm) (Lunetta et al., 2006). Thus NDVI information is generated by focusing on the satellite bands that are most sensitive to vegetation information (near-infrared and red). NDVI is the ratio between the difference of the red reflectance values from the near-infrared to the sum of near-infrared and red bands: NDVI= (NIR-RED) / (NIR+RED). Thus, bigger the difference between the two bands, the more will be the vegetation.

Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice value less than 0 represents no vegetation that includes bare soil, water, clouds, ice, snow; and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. (Feature articles, earthobservatory.nasa.gov)

3. Study Area

The East Kolkata Wetland Area (EKWA) is located along the eastern part of the Kolkata city, approximately between 22°25' to 22°40' latitude North and 88°20' to 88°35' longitude East (Figure 1). The area got the recognition as "Wetlands of International Importance" under Ramsar Convention in 2002 for its unique properties as Waste Recycling Region (WRR). The protected area spreads over approximately 125 km^2 of which the wetland encompasses approximately 40 km^2 (Information Sheet on Ramsar Wetlands 2002). The area comprises of around 254 sewage-fed fisheries, along with agricultural lands, horticulture, garbage dumping fields and some built-up areas (Kundu et al., 2008). Most of the agricultural lands are cultivated either by sewage water released from the fisheries or deep tube-well, only few are rain-fed. The area experiences hot and humid monsoon climate. The maximum temperature during summer rises around 40 °C, and winter temperature remains around 10 °C, with annual mean rainfall of about 160 cm concentrated in the months of June to September (IMD 1901–2000).

4. Material and methods

4.1 Datasets

Open source (USGS) Landsat TM and ETM+ datasets were used for three time periods: January, April and October for the years 2002 and 2010. The data were selected on the basis of summer (April), winter (January) and monsoon (October), to map the year round vegetation status (Table 1). The compilation of selected datasets is limited by weather conditions and data availability in open source domain.

4.2 Methodology

All the Landsat datasets were geometrically corrected using the Survey of India Topographical Sheet No. 79B/6, 79B/7, 79B/10 and 79B/11 at 1:50000 (1973), with a total root mean square error (RMSE) less than half of a pixel and geo-coded at 30 m spatial resolution using nearest neighbourhood re-sampling method with first order polynomial. Next, subsets were extracted in the image processing environment for the said study area.

NDVI image was generated from all the six datasets. The outputs were a set of 8 bit gray-scale images representing the amount of vegetation present at each date. In the resultant images, the bright areas represent regions of high vegetation, while, dark areas show regions of low vegetation. Thus, in the study area, the wetlands, open spaces and settlements appear dark. Meanwhile, agriculture and natural vegetation appears in lighter tone with different brightness value. The three NDVI grayscale images of each time period (2002 and 2010) were then assigned to an individual channel of a RGB display, which were later stacked together to get the composite NDVI image for 2002 and 2010. The January NDVI image was assigned to the blue channel, the April NDVI image was assigned to green, and the October NDVI image was assigned to the red channel (Figure 2). From the RGB display of the images, eight colour classes can be identified, namely, blue, green, red, cyan, yellow, pink, gray and white.

Table 1: Datasets used

Imagery date	Sensor Type
04 January 2001	Landsat ETM+
13 April 2002	Landsat ETM+
22 October 2002	Landsat ETM+
21 January 2010	Landsat TM
11 April 2010	Landsat TM
28 October 2010	Landsat ETM+

Accordingly for composite NDVI classified mapping, the composite NDVI images of both the time periods were classified into ten classes (with 20 iterations and 5% change threshold) by the unsupervised Isodata method. ISODATA unsupervised classification first calculates the class means evenly distributed in the data space, and then by using minimum distance techniques iteratively clusters the remaining pixels. The ten classes so obtained, were merged into eight classes (three classes of non-vegetated types were merged into one). Land cover classes were assigned based on the analyst's knowledge of the landscape and spectral patterns, and this was aided by Panchayat level landuse map (2008) of EKWA prepared by WBPHED, Govt of West Bengal and cropping data from miscellaneous sources. These two classified images were visually interpreted and compared to detect the status of cropping pattern for each time period of the study area.

5. Results and discussion

NDVI production followed by image stacking as three band image and classification results in an easily interpretable and extremely quick approach to determine vegetation change detection. From the composite images for 2002 and 2010, overall vegetation status of the region for both the periods is clearly identifiable. In the colour index of Figure 2, it is visible that beside the assigned blue, green and red, an array of other colours are also present. Cyans are the patches representing vegetation presence between January and April. The yellow areas are those which have vegetation during April and October. Pink areas are the vegetation gain during October and January, and so on. Permanent vegetated area that remained constantly vegetated throughout the time period appears light (whitish)

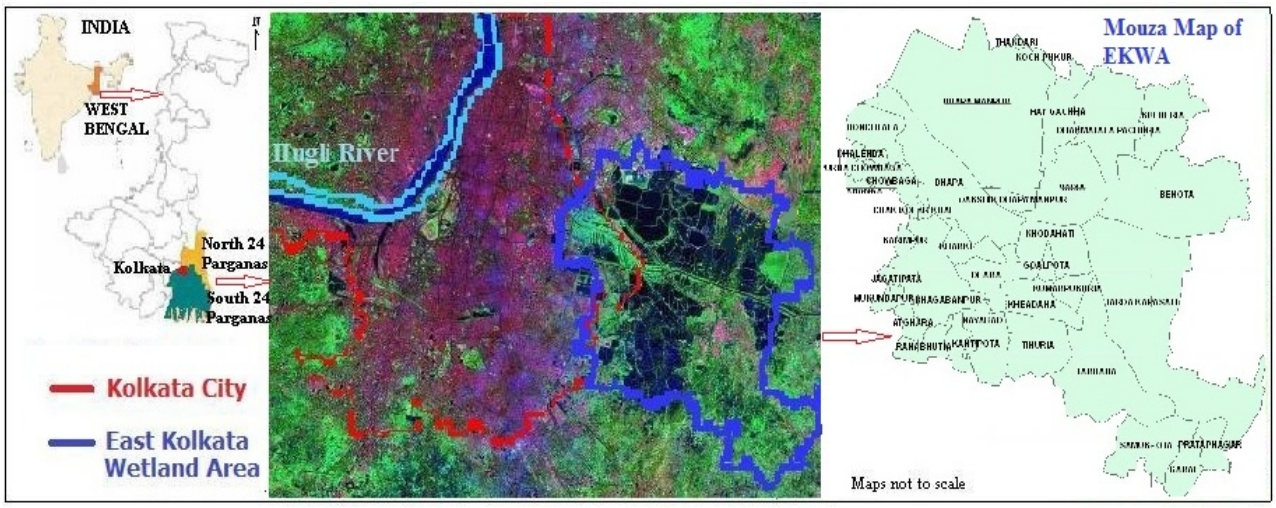

Figure 1: Location map of the East Kolkata Wetland Area (EKWA)

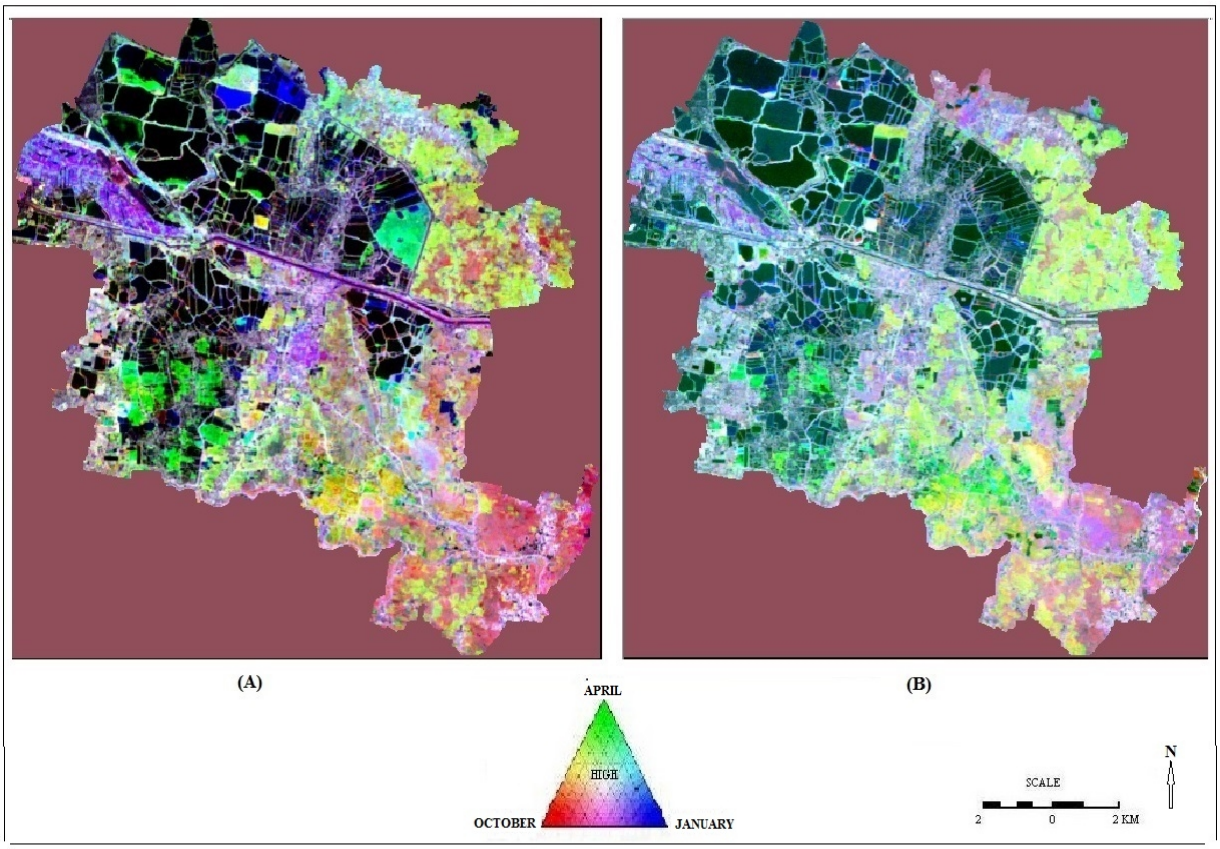

Figure 2: NDVI composite image: (A) 2002, (B) 2010

The areas with presence and absence of vegetation have been categorized into eight classes by unsupervised ISODATA method as mentioned earlier (Figure 3). Thus these eight specific classes are showing the areas with : Class1- Cropland type-I, Class 2- Cropland type-II, Class 3- Cropland type-III, Class 4- Cropland type-IV, Class 5- Cropland type-V, Class 6- Permanent/ Constant vegetated land, Class 7- Waterlogged waste land and Class 8- Non-vegetated region. Cropland type-I are the agricultural lands where crops have been noticed in both April and October. Cropland type-II are the ones with either under paddy sapling cultivation or wetlands under outgrowth of water hyacinth. Cropland type-III are the areas that remain fallow round the year except in monsoon. Thus these are mainly rain-fed agriculture fields. In this region, the areas under cropland type-IV are mostly under horticulture, which are mainly practiced in post-monsoon and winter months. The Cropland type-V are the areas that are either under mixed cropping (mustard, linseed and paddy) or horticulture. Class 6 of cropping pattern is the Constant Vegetated Region, which includes patches of land that remain vegetated throughout the year by natural vegetation (i.e., trees, shrubs etc) and portions of water bodies covered with water hyacinth throughout the year. Since, the croplands cultivated thrice a year are nearly missing in the area, so they have not been considered under

permanent/ constant vegetated region (Bunting et al., 2011). Class 7 is waterlogged waste land, which becomes waterlogged during monsoon and remains barren for rest of the year. The wetlands, open spaces (including barren land) and settlements are categorized under non-vegetated class.

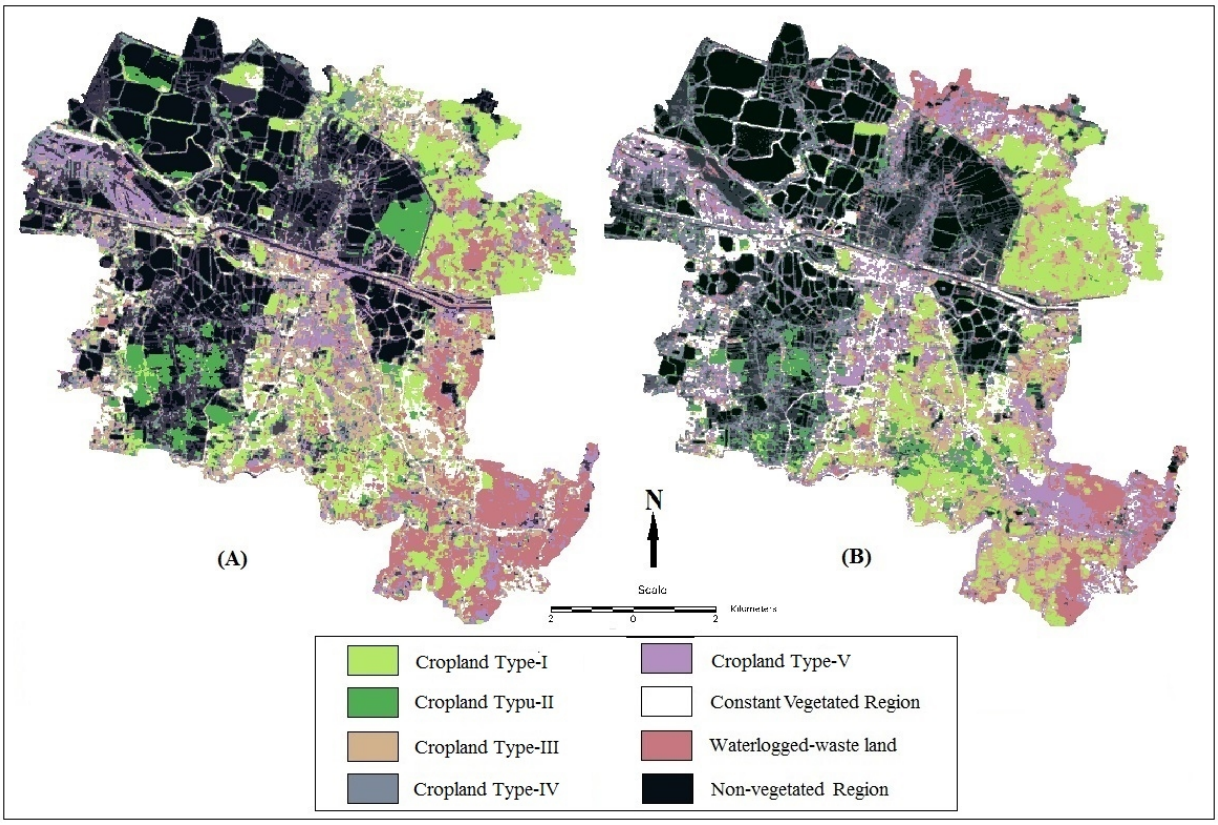

Figure 3. Unsupervised classified images: (A) 2002, (B) 2010

Predominance of kharif crops is mainly visible in the northeastern and southern part of the study area. They are categorized under Cropland type-I. These regions are mainly dominated by paddy cultivation. In 2010 the cultivation in north-eastern portion is more compact compared to 2002, although in both the periods it is in scattered patches in the southern portion. One probable reason for this may be the improved application of ground water and canal lifted sewage water distribution in the north-east during 2010. However the area under Cropland type-I in 2002 is more than that of 2010 (see Table 2), since some of the wetlands covered with water hyacinth in the north of study site during 2002 has been misclassified under this category. Similar misclassification is visible for crops under Cropland type-II. In 2002, some of the water bodies in the north and east of the wetlands are covered with water hyacinth, since they have more or less same reflectance to that of the paddy sapling cultivation, they have been classified under same class. In past NDVI had been applied to monitor water hyacinth (Venugopal, 1998). Water hyacinth is very common in these wetlands, fishermen maintains a 3-4 m wide band around the pond margins for a number of reasons: they save the pond banks from being eroded by the surface waves, provides shade to the fishes during summer, their roots absorb the heavy metals present in the wastewater, are used as buffalo feed and are decomposed on-site as feed for carps.

About 12% – 13% of the total area of the study site remains fallow round the year except in monsoon (Figure 4). Thus, the agricultural lands under Cropland type-III are rain-faded. Since these croplands are located away from the wetlands towards the southeast of the EKWA, they receive very less or no sewage water from the fishponds. Status of such croplands has decreased by nearly 2 % (2 sq. km) between 2002 and 2010. As mentioned earlier that the areas under Cropland type- IV are mostly under horticulture. This type of croplands is mainly distributed along the embankments of the water bodies and Dhapa land fill area. During winter months large variety of vegetables, along with mustard and linseed are grown. Proportion of such lands has increased from 9% in 2002 to 11.4% in 2010. Rest of the croplands which were non-vegetated in April, but were found vegetated during both October and January, are under Cropland type-V. These types of croplands are mainly concentrated in the western (Dhapamanpur mouza), northern (Hatgachha, Dharamatala Panchuria and Kulberia) and central part of the study area; close to the fishponds and canals for sewage water supply. These are double cropped regions i.e., both kharif and rabi crops are grown here. In 2010, some croplands of south-eastern portion have also brought under double cropping, leading to increase in double cropped regions from 11.08 km^2 in 2002 to 13.80 km^2 in 2010.

Landcover that are vegetated throughout the year are mainly natural vegetations and water hyacinth along

the wetland boundaries. 1.08% increase is noticed in this category of vegetation between 2002 and 2010, which may be due to the initiation of aforestation programmes by Government and NGO in recent times. The south-eastern portion of the study site in both periods is under waterlogged wasteland category. Some of the reclaimed croplands at the northern extreme of the EKWA have been converted into waterlogged wasteland. However, as a whole reduction in waterlogged wasteland area from 10.3% to 6.7% has been noticed between 2002 and 2010. Maximum reduction has taken place in the south-eastern portion of the study area. The probable reason may be the desiltation of the canals of this area, leading to less spilling of canal water and conversion of such lands into Cropland type-I and type-II. The non-vegetated area has decreased in 2010 from 2002 suggesting decline in wetland area due to the conversion of fishponds into other landcover classes.

Table 2: Area under different landcover classes

Classes	2002		2010	
	Area in km^2	Area in %	Area in km^2	Area in %
Cropland type-I	16.57	13.25	15.87	12.70
Cropland type-II	5.51	4.41	7.13	5.71
Cropland type-III	16.70	13.36	14.33	11.46
Cropland type-IV	11.06	8.84	14.24	11.39
Cropland type-V	11.08	8.86	13.83	11.06
Constant vegetated land	8.00	6.40	9.35	7.48
Waterlogged waste land	12.88	10.30	8.36	6.68
Non-vegetated land	43.21	34.57	41.88	33.51
Total area	**125.00**	**100.00**	**125.00**	**100.00**

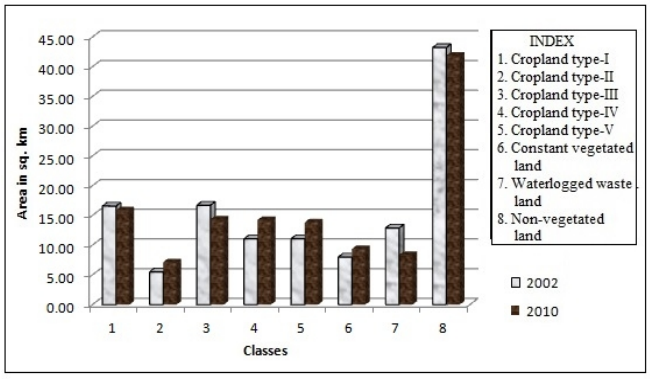

Figure 4: Vegetation status of East Kolkata Wetland Area for 2002 and 2010.

6. Conclusion

NDVI change detection technique for vegetation mapping works well to identify the cropping pattern and vegetation character of the study site. The vegetation status maps of 2002 and 2010 show approximately 78% and 76% accuracy respectively with respect to the Panchayat level landuse/ landcover map (2008) of EKWA prepared by WBPHED, Govt of West Bengal, with reference to Google Earth Imageries. Through NDVI composite mapping difference between agriculture and natural vegetation is well detected, since agriculture follows different growth cycles. Thus Vegetation status and cropping pattern mapping applying NDVI calculated from Landsat-TM and ETM+ data provides good representation of the vegetation condition of the study area throughout the year. Thus the composite NDVI classified mapping technique applied to Landsat TM imagery appears to be a promising technique for monitoring vegetation status.

References

Asrar, G., M. Fuchs, E. T. Kanemasu and J. L Hatfield (1984). Estimating absorbed photosynthetically active radiation and leaf area index from spectral reflectance in wheat. Agronomy Journal, 76, 300–306.

Bannari, A., D. Morin and F. Bonn (1995). A review of vegetation indices. Remote Sensing Reviews, 13, pp. 95– 120.

Bunting, S.W., P. Edward and N. Kundu (2011). Environmental management manual: East Kolkata Wetlands, Manak Publication Pvt. Ltd, India, p.64.

Coppin, P. R. and M. E. Bauer (1994). Processing of multitemporal Landsat TM imagery to optimize extraction of forest cover change features, IEEE Trans. Geosci. Remote Sens. 32(4), pp. 918-927.

Gitas, I., G. Mitri, S. Veraverbeke and A. Polychronaki (2012). Advances in remote sensing of post-fire vegetation recovery monitoring – A review. In: Fatoyinbo, T., (Ed.) Remote Sensing of Biomass – Principles and Applications. Published by InTech, Croatia.

Gobron, N., B. Pinty, M. M. Verstraete and J.L. Widlowski (2000). Advanced vegetation indices optimized for upcoming sensors: design, performance, and applications. IEEE Transactions on Geoscience and Remote Sensing, 38 (6), pp. 2489– 2505.

Goward, S. N., C. J. Tucker and D. G. Dye (1985). North American vegetation patterns observed with the NOAA-7 advanced very high resolution radiometer. Vegetatio, 64, pp. 3–14.

India Meteorological Department (IMD) database (1901–2000). Available from: http://

www.imd.gov.in/section/nhac/mean/kolkata.htm [Accessed on 23 April 2012].

Information Sheet on Ramsar Wetlands (2002). Categories approved by Recommendation 4.7 of the Conference of the Contracting Parties, on The East Calcutta Wetlands, India [online]. Available from: http://www.wetlands.org/reports/ris/2IN013en.pdf [Accessed on 10 March 2011].

Justice, C.O., J.R.G. Townshend and V.L. Kalb (1991). Representation of vegetation by continental data sets derived from NOAA-AVHRR data. International Journal of Remote Sensing, 12(5), 999-1021.

Knight, J.K., R.L. Lunetta, J. Ediriwickrema and S. Khorram (2006). Regional scale land cover characterization using MODIS-NDVI 250 m multi-temporal imagery: A phenology based approach. GIScience and Remote Sensing (Special Issue on Multi- Temporal Imagery Analysis), 43(1), pp. 1-23.

Kundu, N., M. Pal and S. Saha (2008). East Kolkata wetlands: a resource recovery system through productive activities. In: M. Sengupta and R. Dalwani, (Eds.) Proceedings of Taal2007: The 12th World Lake Conference. India: Ministry of Environment and Forest, xiii–xxii, 868–881.

Lenney, M.P., C.E. Woodcock, J.B. Collins and H. Hamdi (1996) The status of agricultural lands in Egypt: The use of multitemporal NDVI features derived from Landsat TM, Remote Sensing of Environment, 56(1), pp. 8-20.

Lillesand, T.M., R.W. Kiefer and J.W. Chipman (2004). Remote sensing and image interpretation. 5th Edition, John Wiley and Sons (Asia) Pte Ltd. New York. p.469.

Lunetta, R.S., J.F. Knight, J. Ediriwickrema, J.G. Lyon and L.D. Worthy (2006). Land-cover change detection using multi-temporal MODIS NDVI data. Remote Sensing of Environment, 105, pp. 142-154.

Michener, W. K. and P. F. Houhoulis (1997). Detection of vegetation changes associated with extensive flooding in a forested ecosystem. Photogramm. Eng. Remote Sens. 63, pp. 1363–1374.

Purevdorj, R., T. Tatelshi and Y. Ishiyama (1998) Relationships between percent vegetation cover and vegetation indices, International Journal of Remote Sensing, 19 (18), 3519-3535.

Ribeiro, N., M. Cumbana, F. Mamugy and A. Chauque (2012). Remote sensing of biomass in the Miombo woodlands of Southern Africa: Opportunities and limitations for research. In Fatoyinbo, T., (Ed.) Remote Sensing of Biomass – Principles and Applications. Published by InTech, Croatia.

Sakamoto, T., M. Yokozawa, H. Toritani, M. Shibayama, N. Ishitsuka and H. Oho (2005). A crop phenology detection method using time-series MODIS data. Remote Sensing of Environment, 96, pp. 366-374.

Townshend, J.R.G. and C.O. Justice (1986). Analysis of the dynamics of African vegetation using the normalized difference vegetation index. International Journal of Remote Sensing, 8(8), 1189- 1207.

Venugopal, G. (1998). Monitoring the effects of biological control of water hyacinths using remotely sensed data: A case study of Bangalore, India. Singapore Journal of Tropical Geography, 19, 91–105.

Xiao, X., S. Boles, S. Frolking, W. Salas, B. Moore III, C. Li, L. He and R. Zhao (2002). Landscape-scale characterization of cropland in China using Vegetation and Landsat TM images, International Journal of Remote Sensing, 23(18), 3579-3594.

Measuring Vegetation (NDVI & EVI): Feature Articles, earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php [Accessed on September 9, 2012].

USGS: Landsat Data downloaded from: http://glovis.usgs.gov