Semi-Automated Methods for Wetland Mapping Using Landsat ETM+: A Case Study from Tsunami Affected Panchyats of Alappad & Arattupuzha, South Kerala

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Abstract: ***The global extent of wetlands are under continuous loss and degradation which have resulted in diminished ecosystem services, and also are facing several challenges .So systematic mapping and inventorying is essential for the assessment of their ecological health and integrity. The traditional methods of monitoring wetlands by using field survey and labor force are time and labour intensive. Modern and advanced technologies such as remote sensing and GIS offer the opportunity to map and inventory wetlands rapidly and consistently, irrespective of the geographic location. The present study utilizes a semi-automated method for mapping wetlands using LANDSAT ETM+ and ASTER DEM data. Various spectral and terrain indices, viz., Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Tasseled Cap Wetness Index (TCWI)and terrain slope were used for the extraction of wetland areas. The thresholds for the indices were finalized based on trial and error method in order to avoid overestimation or underestimation of wetland areas. Nearly 80 % of accuracy was observed for the present wetland delineation methodology by comparing the data with Google Earth. The methodology was evaluated for the Tsunami affected Panchayats of Alappad & Arattupuzha, Kerala, India. As the villages lie in the coastal areas,the landscape consists of almost lowland plains. The present methodology can be used to understand the spatial distribution of different wetlands and association with disaster risk reduction initiatives.***

Keywords: Wetland mapping, semi-automated methods, spectral indices,Tsunami, Alappad&Arattupuzha, Kerala

1. Introduction

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al., 1979; Lyon, 1993).As one of the most important ecosystems in the earth, wetlands are one of the most important environmental resources, which are named "kidney of the earth".. Further, wetlands play important role in many environmental functions including bio-geochemical cycling, regulation of the hydrological cycle and flood control, erosion control and shoreline protection, improvement and protection of water quality, recharging of aquifers and habitat for wildlife, and fisheries and resources for human communities (Coughanowr, 1998; Naiman et al., 1998; Islam et al., 2008).Nowadays, Remote Sensing data have been widely used in the researches of wetlands as they offer timely, up-to-date, and relatively accurate information for sustainable and effective management of wetland (Adam et al, 2010). Because of its repetitive coverage and ability to integrate into a geographic information system (GIS) it can be widely used for inventorying and monitoring wetlands..The spectral values of some specific sensor channels can be used to extract wetland information from environment. The ASTER and ETM+ data are particularly the appropriate sources for the semi automated method for classification of wetlands. Spectral indices play a major role in Remote sensing technology. The present study also utilizes a variety of spectral indices which have been developed for retrieving wetland information from l remote sensing imagery. The most widely measurement used in the study includes the Normalized Difference Vegetation Index (NDVI) .Commonly NDVI analysis is used for Vegetation detection but here it is mainly used to delineate the wetland areas. Next parameter is the Normalized Difference Water Index (NDWI) ,it is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels which is used to delineate land from open water. Tasseled cap transformation is also used to detect the presence of wetness in the area. Tasseled cap wetness image is generated which clearly highlights the wetness portions for the extraction of the wetlands. Slope acts as a topographic unit which indicates the relative angle of the ground with respect to earth mean surface. A resultant slope image reveals spatial distribution of relative elevation of surrounding pixels. In the study, a slope image was created using the ASTER DEM.

2. Definition

Prior to the identification and mapping of wetlands, it is essential to understand the criteria of a region being classified under the wetland category. Even though there are several wetland classifications, the definitions provided by Ramsar convention and United States Geological Survey (USGS) are the most widely used. The Ramsar convention defined wetlands as " areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters". However, the USGS defined wetland as a general term applied to land areas which are seasonally or permanently waterlogged, including lakes, rivers, estuaries, and freshwater marshes; an area of low-lying land submerged or inundated periodically by fresh or saline water (Cowardin et al. 1979).

3. Study Area

Alappad and Arattupuzhaare two coastal bordering Panchayat of Kollam and Alappuzha district in Southern Kerala. The Kayalamkuma estuary bordered administratively these areas into two administrative blocks(Panchayat).The total geographical spread of these Panchayat is 30 sq km. Physiographically this is one most vulnerable coastal area in state because strip has a maximum width of less than 1 km and is bound by the open coast on the west and Kayanakulam Lake and backwaters on the east. Geomorphologic ally this area is a narrow stretch of barrier bar where having 200 m to 500 m width Tsunami event has exposed unique physiography of the Alappad-Arattuzpha stretch that caused relatively high havoc. In the state maximum devastation was in Alappad-Arattupuzha stretch on both side of the Kayamkulam outlet in the low land segment(Chattopadhayay, et. al 2006 ; Narayana et al 2007).. A small opening in the strip connects the lake to the sea. The width of the land strip is less than 0.5 km at many places. As a result, the tsunami waves struck the entire strip of land, travelled across the backwaters, and rolled onto the opposite bank (Sheth, et al 2006). The largest number of casualties 165 in Kerala from these two Pachyats. Also around 4000 houses fully damaged and another 3000 houses were partially destroyed in this part of Kerala. Damage due to the tsunami was maximum in sectors adjoining Kayamkulam inlet in southern Kerala. Towards north and south of this zone, damage was less extensive. (Kurian et al, 2006) So in post tsunami, these streatch received the maximum attention from the government for Reconstruction & Rehabilitation activities.

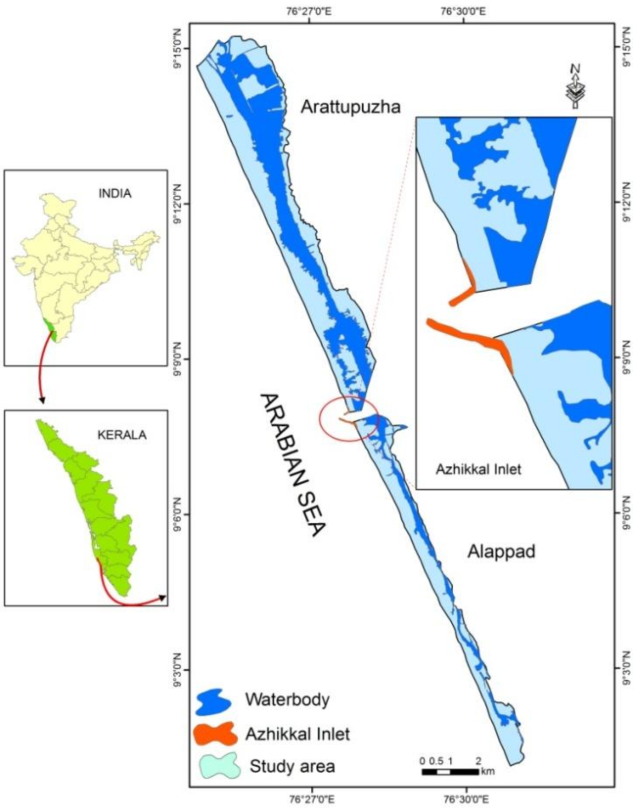

Figure 1: Study Area

4. Data Products and Derivatives

The primary data in this study includes Landsat Enhanced Thematic Mapper (ETM+)data (8 bands, 30 m spatial resolution)for the year 2013 and the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER).The rationale behind the selection of these data is the nearly global coverage, well calibrated and processed data and free availability.

The paper utilizes mainly four indices (including spectral and terrain), viz., Normalized Difference Water Index (NDWI), normalized difference vegetation index (NDVI), Tasseled Cap Wetness (TCWI) and terrain slope were used for the identification of wetland areas .The threshold values for the classification of wetland areas were based on "trial and error" experimentation conducted using these indices and varying their thresholds to determine maximum seperability of the wetlands from other land units.

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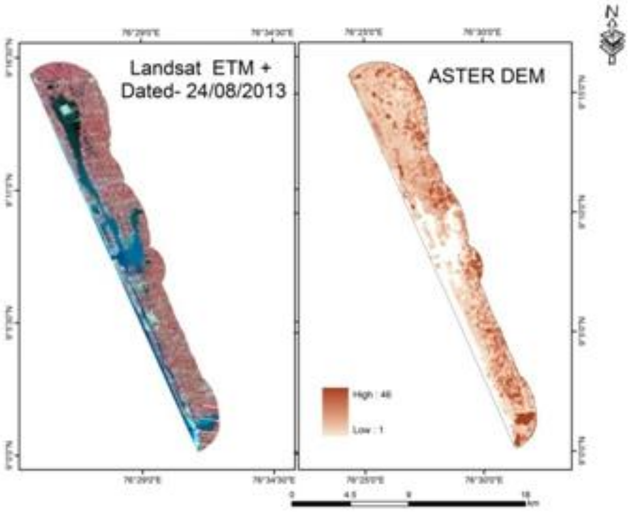

Figure 2: Data used

4.1 NDVI, NDWI, and Tasseled Cap Wetness index

NDVI is an array of values derived from satellite data which is useful for vegetation mapping. It is one of the most widely used vegetation indexes (Zhu et al, 2001). Tucker (1979) developed the Normalised Difference Vegetation Index (NDVI) using the two bands of light: red and near-infrared. It is used to measure of the vegetation cover and also water bodies over the earth surface (Tucker and Choudhury 1987, Jackson and Huete 1991). Following Tucker (1979), it is found that the NDVI value ranges from -1 to +1. Here, +1 describes the dense vegetation. Water typically has an NDVI value of less than zero. Here the NDVI ranges from - 0.44-1. Negative values of NDVI are mainly observed in water bodies and flooded area. So the negative value range has been used to calculate the wetland area.

Normalised Difference Water Index (NDWI) of McFeeters (1996) and Xu (2006) is to achieve the signature differences between water and other targets through analyzing signature features of each ground target among different spectral bands, and then to delineate land from open water. According to Sims and Gamon (2003), the NDWI is an appropriate water absorption index in comparison with NDVI. It also ranges from -1 to +1 (McFeeters 1996). Chowdary (2008) mentioned that it is for water-logged areas ranges from zero to +1. Here, +1 signifies the presence of extensive deep water bodies and -1 is for vegetation cover. In the present study the value ranges from -1-0.6. The threshold is set as zero . That is, the cover type is water if NDWI > 0 and it is non-water if NDWI ≤0

Tasseled cap transformation (TCT) is a linear transformation which reduces overlapping of multi-spectral datasets into fewer number of image based on particular scene characteristics. Three main transformed images namely soil brightness, greenness vegetation, and wetness soil/vegetation are produced by this transformation. The present study concentrates only the wetness image of TCT to extract the wetlands. The wetness component contrast the sum of the visible and near infrared bands with the longer infrared bands to determine the amount of moisture being held by the vegetation or soils (Lea et, al. 2003).
Similarly, wetlands are associated with topographic low profiles, hence< 1^0slope has been chosen

Table 1: Various indices used for wetland delineation

Sl. No.	*Index/Parameter*	*Definition*
1	Normalized Difference Water Index (NDWI)	*NDWI*= R_{NIR} -R_{SWIR}/ R_{NIR+} R_{SWIR} Where R_{NIR} and R_{SWIR} correspond to bands 4 (0.78 – 0.90 µm) and 5 (1.55 – 1.75 µm) of Landsat ETM+ data respectively
2	Normalized Difference Vegetation Index (NDVI)	*NDVI* = R_{NIR} -R_{RED} /R_{NIR} + R_{RED} Where R_{NIR} and R_{RED} correspond to bands 4 (0.78 – 0.90µm) and 3 (0.63 – 0.69 µm) of Landsat ETM+ data respectively
3	Tasseled Cap Wetness Index (TCWI)	Tasseled cap wetness index$_i$= (0.2626*B1)+ (0.2141*B2)+(0.0926*B3)+ (0.0656*B4)+ (-0.7629*B5)+ (-0.5388*B7). where B1 to B7 are the DN values of the respective bands of Landsat ETM+ data. This index represents the overall degree of wetness over the area as reflected by image data. Huang et al. (2002)
4	Slope (in degree)	Degree slope derived using Spatial Analyst tools available in Arc GIS

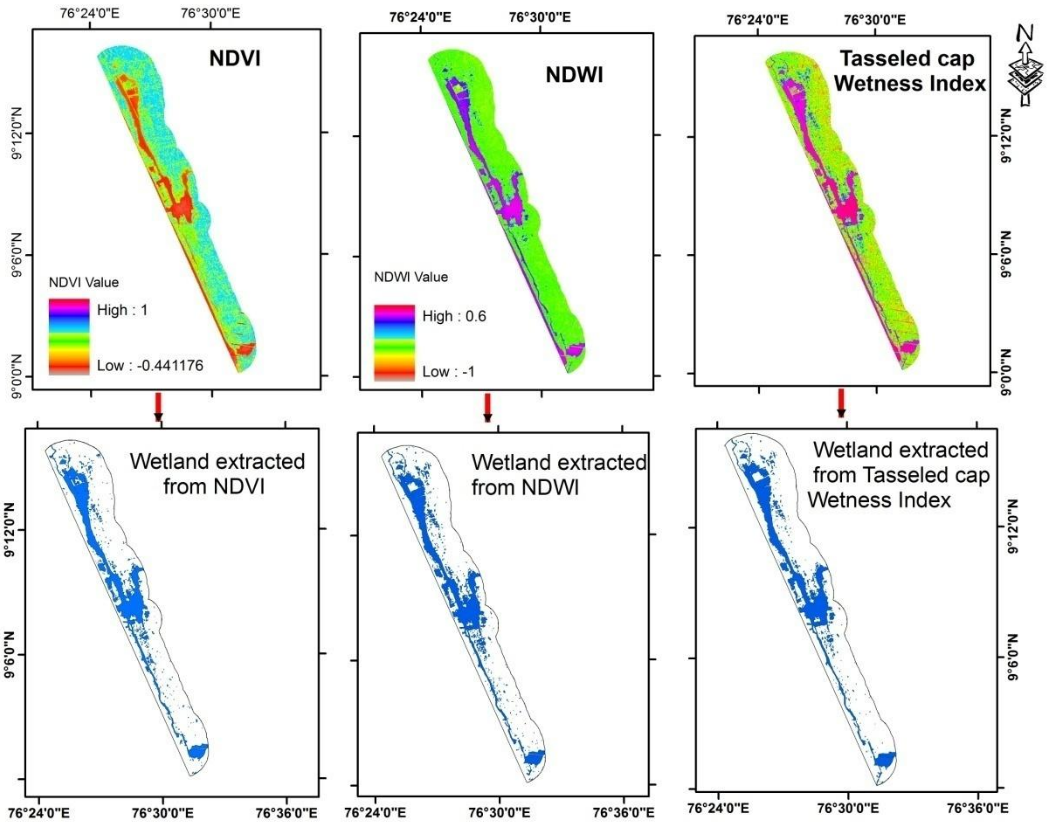

Figure 3: Various spectral Indices and their corresponding extracted wetlands

In addition, Image enhancement techniques to highlight the wetlands from the neighboring landscape and image display techniques involving the use of various false color composites (FCCs) of Landsat ETM+ data were also used to delineate wetland boundaries from other land units.

For example,

- ETM+ 4/ETM + 7, ETM+ 4/ETM + 3, ETM+ 4/ETM + 2,
- ETM+ 4, ETM+ 3, ETM+ 5,
- ETM+ 7, ETM+ 4, ETM+2 and
- ETM+ 3, ETM+ 2, ETM+ 1.

Overlay analysis of the individual themes was carried out in ArcGIS 9.3 to delineate the final map. After delineation of the preliminary wetland boundary, the map was rechecked with Google earth to assess the accuracy. Minimal corrections and edits have been made by manual onscreen digitizing.

5. Results and Discussion

The resultant wetlands derived from various indices, image enhancement techniques along with the slope are extracted separately. The different wetland themes generated from different sources were combined together to form one single theme. Union function is applied for all extracted wetland themes. The resultant function clearly gives an output of the wetland derived from all the themes. Out of the total 103 km² of the Alappad & Arattupuzhapanchayats, the wetland consists of nearly 23 %area, which has revealed the importance of wetlands in the coastal area.

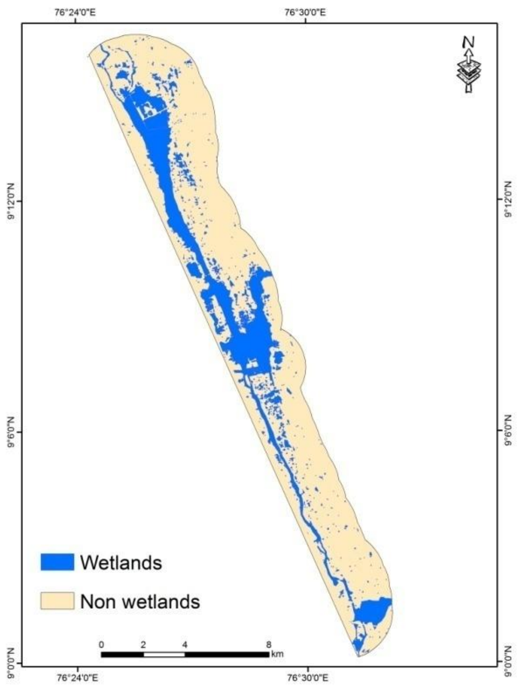

Figure 4: Wetland areas delineated from Landsat ETM+ and ASTER DEM data

Wetland areas delineated from Landsat ETM+ and ASTER DEM data is very important in the tsunami affected area since wetlands were the geomorphic feature directly came under impact by the 2004 Tsunami. The tsunami inundation into the hinterland regions is relatively less in Kerala due to the occurrences of coast parallel backwaters/lagoons and is particularly relevant in the study area where wetland cover 23 % of the area. It particularly affected wetlands lies the north and south of Kayamkulam inlet in the Alappad and ArattupuzhaPachayat. Flooding occurred either due to the entry of water that crossed over the shores or due to inundation through the tidal inlets. It is quite possible that these inundations could cause considerable siltation of the backwaters due to the sediments brought in by the inundation, particularly in the backdrop of the erosive tendency of the tsunami as is seen already. It is already reported that the inundation brought deposits as thick as about a meter on the coastal roads of Kayamkulam inlet area (Narayana et al. 2005; Kurian et al. 2005). The area mainly witnessed both siltation and erosion. It may be noted that this was the zone where the inundation was high with a maximum run-up of 5 m. (Kurian e. al 2006).

6. Conclusion

In the post tsunami context manystretch of wetlands in the study have been used for various rehabilitation purposes including housing shelter and infrastructural development such as roads and bridges. A separate study will be followed on the impact of the rehabilitation initiative in the areas impacted on wetlands. Themethodology used in this study clearly gives a perfect picture about the present status of wetlands and is also ideal for other areas dominated by wetlands. As the coastal wetlands are more exposed to coastal hazards the aforesaid methodology has its own importance on disaster risk reduction initiatives

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