Coastal Wasteland Identification and Mapping Using Satellite Data

Gouri Sankar Bhunia[1]; Pravat Kumar Shit[2]; Dilip Kumar Pal[3]

[1]Aarvee Associates Architects, Engineers & Consultants Pvt Ltd, Hyderabad – 500 082, India (Email: rsgis6gouri@gmail.com)

[2]Departmentof Geography, Raja N. L. Khan Women's College, Gope Palace, Medinipur-721102, West Bengal, India (Email: pravatgeo2007@gmail.com)

[3]Department of Surveying and Land Studies, Papua New Guinea University of Technology, Papua New Guinea (Email: dkpal200090@gmail.com)

Abstract

Coastal salt-affected lands are often associated with seasonal fluctuation of the shallow, brackish water table. Impeded drainage typical of coastal ambience is the root cause of salinisation /alkalinisation, which poses severe impediment to sustained irrigated agriculture. Present study was done on a small portion of the Indian side of world's biggest estuarine belt called 'Sundarbans' encompassing the mouth of the sea, Bay of Bengal, spanning through India and Bangladesh. Multi-temporal satellite data were investigated to evaluate the spatial extent of costal wasteland in Sandeshkhali block, North 24 Parganas district in West Bengal, India. Landsat 8 Operational Land Imager (OLI) data of different seasons were used. The coastal wetlands were demarcated through field-based investigation and geographic location of each point was recorded. Normalized Difference Water Index was used to extract the water bodies from the satellite data. Supervised classification technique was adopted to classify coastal wetlands. The total area of wasteland is estimated as 130.86 km^2, which is approximately 34.36% of the total geographical area. Coastal wastelands namely wetlands, coastal sand, salt pan, coastal swamp, scrub land, surface waterlogged areas and tidal salt marsh were identified in the study area. The overall accuracy of the classification results showed 88% along with the overall kappa statistics of 0.84. The study demonstrated high performance of the proposed approach in the surface wasteland identification.

Keywords: *Water logging, remote sensing, normalized difference water index; coastal area*

1. Introduction

Land is facing severe intimidations of worsening because of remorseless, unbridled anthropogenic pressure and also due to the fact that the actual land use is hardly in tune with the capability of the land parcel. Land degradation refers to the land which is worsening due to the dearth of proper water and soil management or on account of natural resources (Saha et al., 1990). Land degradation due to desertification, soil salinity, waterlogging, floods/droughts, excessive soil erosion and unscientific agricultural practices has resulted in the creation of vast stretches of wasteland. Approximately 15% of the world population is exposed to land degradation which is expected to deteriorate in absence of satisfactory and instantaneous actions undertaken to seize the dilapidation processes (UNCCD, 2014). The coastal zone is an intermediate region between the sea and inland areas, containing a chunk of coastal lands, the shoreline and the intertidal/subtidal zones (Sousa et al. 2016). The lower Gangetic plains are drained by several large river systems, which are sternly affected by frequent flooding. Almost each year, seasonal floods in the lower Gangetic plains cause innumerable gloom to the dwellers living on the floodplains.

Evidence based on environmental location, aerial range and spatial dissemination of wastelands is needed for their effective management and supportable improvement (Narayan et al. 1989; NRSC/ISRO, 2012; Goyal et al. 1993; Basavarajappa and Manjunatha, 2014). Remote sensing and GIS have become valuable tools for land resource inventory at local, regional and global scales (Thilagam and Sivasamy, 2013). However, the Landsat data with better spatial and spectral resolution enabled us to map and monitor degraded lands more efficiently (Pushpavathi, 2010; Tagore et al., 2012). In this study, multi-temporal satellite data were used to evaluate the spatial extent of costal wasteland in Sandeshkhali block, North 24 Parganas district in West Bengal, India.

2. Study area

Sandeshkhali block is situated between 22°14'55.338"N - 22°30'27.025"N latitude and 88°43'29.182"E - 88°57'31.665"E longitude of North 24 Pargana district of West Bengal, India (Figure 1), located along the lower Ganga plain and delta. The region is comprised of Ganga-Brahmaputra delta in the southern part, which has broken from the Gondwanaland along the margin of the Indian plate and then moved northerly in the early Cretaceous. The maximum temperature of Sandeshkhali is recorded in May at 41˚C and minimum temperature is recorded in January at 10˚C and with an average annual rainfall of 1,579 mm. Due to heavy and concentrated rainfall, flat topography, low hydraulic conductivity of soil and shallow water table, the block is subjected to intense water logging during monsoon. Geologically, the area is covered by alluvial and deltaic deposits of quaternary period. Physiographically, the region consists in the Archean that metamorphosed to sub-recent and recent alluvium formation.

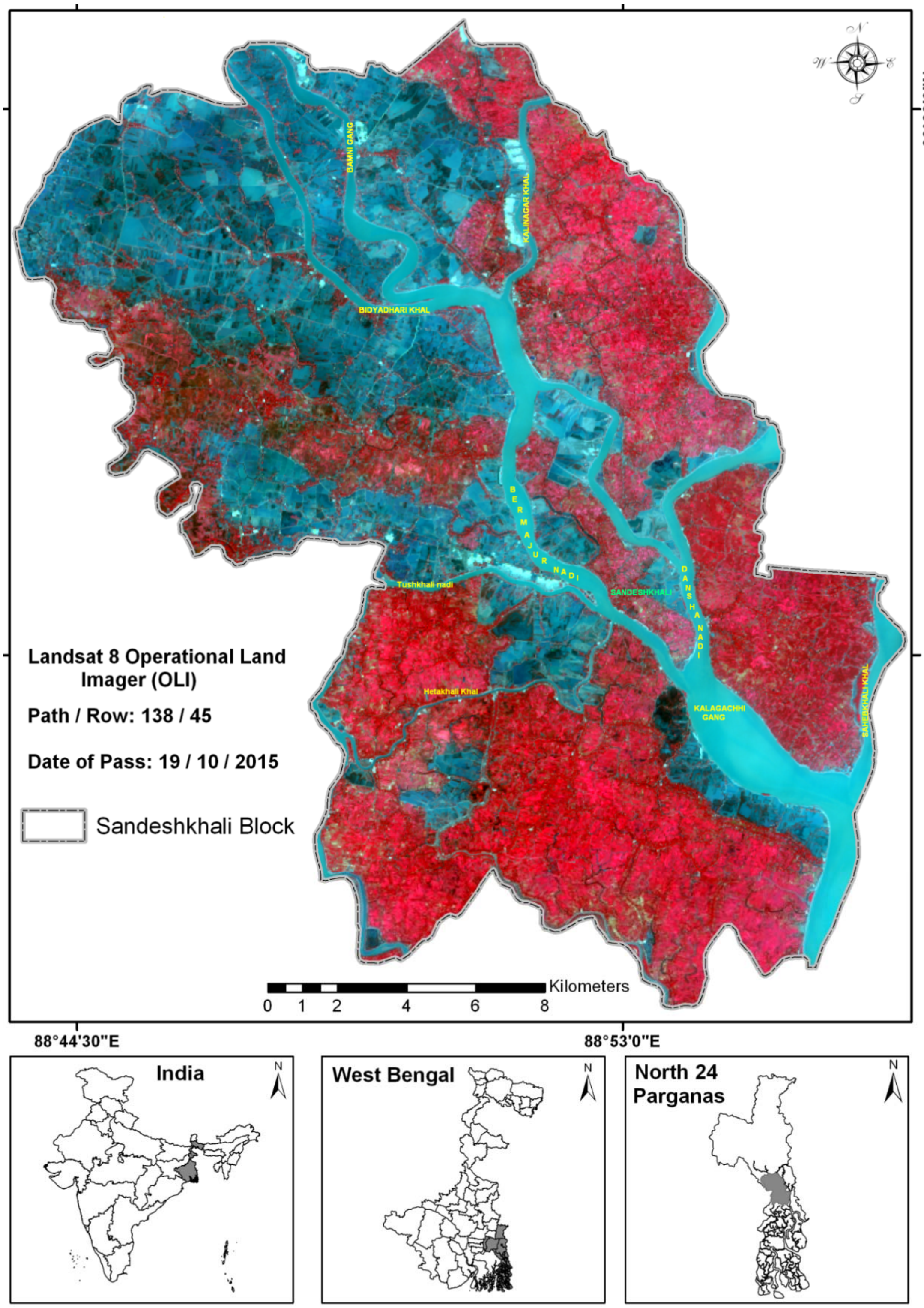

Figure 1: Location map of Sandeshkhali block, North 24 Pargana district, West Bengal (India)

3. Materials and methods

3.1 Data used

The National Atlas and Thematic Mapping Organization (NATMO) District planning Map Series of North 24 Parganas was digitized and was then geo-referenced with the Survey of India Toposheets (79 B/11, 79 B/14, and 79 B/15) on a scale of 1: 50,000. In the present research work, data of Landsat 8 Operational Land Imager (OLI) (Path/Row: 138/45; date of pass: 22/03/2016 and 19/10/2015) have been used. The satellite data were derived from the USGS Earth Explorer community. The individual scenes were geo-coded with control points thereby enabling each scene to return the co-ordinates at each position. All the maps were extracted with a view to creating area of interest (AOI) by the block boundary polygon layer. The image processing operation was performed using ERDAS Imagine software v9.0. Detailed methodology is represented in Figure 2.

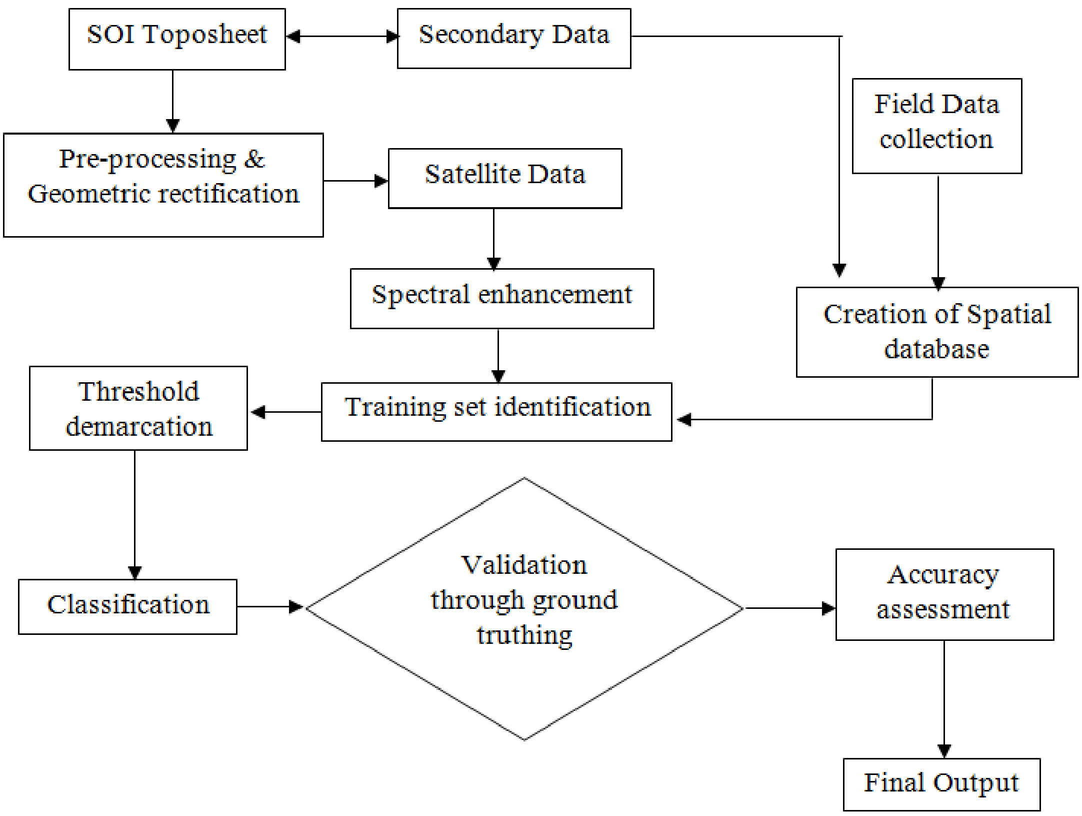

Figure 2: Methodological flowchart

Field survey was carried out during the period between December, 2015 and February, 2016. The ground truth information of different types of coastal wetlands was demarcated. The supervised classification technique based on maximum likelihood algorithm was adopted to classify the satellite data (Shit et al., 2015). Before the classification the image enhancement technique (i.e., Histogram equalization) was applied to increase the contrast of the image. On satellite data the salt pan areas are seen in different tones of dull white to bright white with association of poor crop growth. The scrubland appeared as light yellow to brown depending on the surface moisture cover. The coastal sand appeared as white to light bluish again depending on moisture content. Seasonally waterlogged areas look very clear in diverse shades of blue and cyan in standard false colour composite image. The study areas were classified into a total of nine categories. For each category, five training sites were used to classify the images. After that, statistical filtering (3x3 window size) was used to smoothen the classified image. Recoding technique was adapted to extract the wasteland categories and other supplementary classes were dissolved. Accuracy assessment analysis was performed to estimate the user accuracy and producer accuracy of the classified image. In this assessment, a total of fifty points were randomly collected and verified with the classified map.

To delineate the seasonal water bodies, two season data were applied. Consequently, to extract the surface water bodies, Normalized Difference Water Index (NDWI) was used. In this technique, the green channel (Band-3: 0.53 - 0.59µm) and Shortwave infrared channel (Band-7: 2.11 - 2.29µm) were applied. The NDWI (McFeeters, 1996) was calculated as:

$$NDWI = \frac{X - Y}{X + Y}$$ Equation ……………………………(1)

Where, X = $Band_3$: Green Channel (0.53 - 0.59µm) and Y = $Band_7$: Shortwave infrared channel (2.11 - 2.29µm)

The outcomes from NDWI equation are water features that have positive values while soil and terrestrial vegetation have zero or negative values. After deriving the NDWI output, threshold values were determined and the image was reclassified for the final extraction of water bodies for each season separately. Using the overlay operation in ArcGIS software version9.3, the water bodies were separated into permanent and temporary water bodies. Permanently waterlogged areas were those where the water remains stagnant for most part of the years, and were mostly located in low lying areas, while appearing dark blue in the standard false color image. Temporary waterlogged areas prevail during the monsoon period, associated with the drainage congestion. Areal distributions of both bodies of water were determined.

4. Results and Discussion

Scientific visualisation based on the image appearances and prior information on the study area was conducted to identify wasteland areas. The area receives intensive rainfall during early June to late October, culminating in numerous wasteland groups associated to growth of hydrophytic grasses and weeds. Temporal image of Rabi season (winter, dry period) was utilised for demarcation of various wasteland classes, where separation of various confusing land use/ land cover classes became possible to a large extent. This assisted in better documentation and mapping of wastelands.

Table 1: Areal distribution of wasteland categories in Sandeshkhali block, North 24 Pargana district, West Bengal (India)

Coastal wastelands	Area in Km^2	% of the total wasteland	% of the total geographical area
Coastal sand	7.74	5.92	2.03
Salt pan	0.32	0.25	0.08
Coastal swamp	2.38	1.82	0.62
Scrub land	3.31	2.53	0.87
Surface waterlogged areas	116.27	88.85	30.53
Tidal salt marsh	0.83	0.64	0.22
Total	**130.86**	**100.00**	**34.36**

The study area has been classified into six categories of wasteland, namely coastal sand, salt pan, coastal swamp, scrub land, surface waterlogged areas and tidal salt marsh (Table 1). The total area of wasteland is estimated as 130.86 km^2, which is approximately 34.36% of the total geographical area. In respect to total geographical area, the maximum concentrations are found as surface waterlogged, which is distributed in the northern and the central part of the study area (Figure 3). The areal extents of the surface waterlogged areas are 88.85% of the total wasteland area in Sandeshkhali Block and 30.53% of the total geographic area (Table 1). The coastal sand is distributed as 5.92% of the total wasteland area, found along the course of Kalagachhi Gang, BermajurNadi, Bamni Gang, DanshaNadi, BidyadharKhal, and KalinagarKhal. The salt pans are the small shallow pools with salt encrustation (Pethick, 1974). The small patches of salt pan are distributed along the course of Kalianagarkhal and Tushkhalinadi, distributed in the north-east, northern and central part of the Sandeshkhali block. However, salt pan cover only 0.08% of the total geographic area (Table 2).

Table 2: Accuracy assessment report of wasteland group in Sandeshkhali block, North 24 Pargana district, West Bengal (India)

Class	Reference Totals	Classified Totals	Number Correct	Producer Accuracy	User Accuracy	Kappa Statistics
Coastal sand	7	6	6	85.71%	100.00%	1
Salt pan	4	5	4	100.00%	80.00%	0.7826
Coastal swamps	6	5	4	66.67%	80.00%	0.7727
Scrub land	6	6	5	83.33%	83.33%	0.8106
Surface waterlogged areas	20	23	20	100.00%	86.96%	0.7826
Tidal salt marsh	7	5	5	71.43%	100.00%	1
Totals	**50**	**50**	**44**			
Overall Classification Accuracy = 88.00%						
Overall Kappa Statistics = 0.8402						

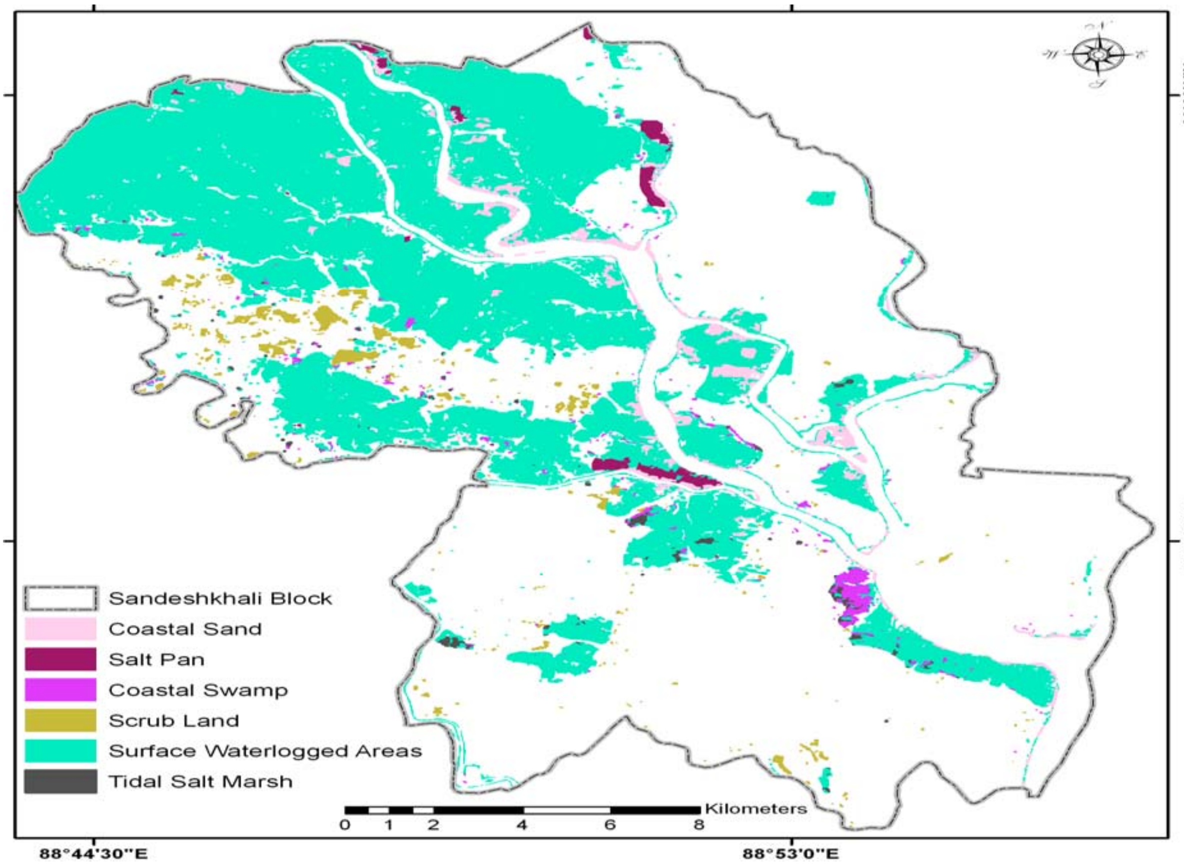

Figure 3: Spatial aspect of wasteland distribution in Sandeshkhali block, North 24 Pargana district, West Bengal (India).

The coastal swamps are permanently or periodically inundated by water and are characterized by vegetation, which includes grasses and reeds. There are very small patches of coastal swamps distributed across the entire block, covering approximately 0.62% of the total geographic area. The scrub dominated land constitutes about 3.31km^2 which is approximately 0.87% of the total geographic area. The scrub land is mainly distributed in the eastern and some small patches in the central part of the block that may be due to the poor soil. Waterlogging is also diligently connected with salinization / alkalization, to be considered to persistent irrigated agriculture (NWDB, 1987; Sharma et al., 2005). It is estimated that 64.22 km^2 and 44.84 km^2 areas are covered by permanent and temporary waterlogging respectively (Fig. 4). With the course of time, the surface boundaries of such waterlogged areas become desiccated (temporary waterlogged) and only central part (core area) vestiges waterlogged (permanent waterlogged). The waterlogged areas are mainly distributed in the northern and north-east and some small patches of central part of Sandeshkhali block.

The overall accuracy of the classification results showed 88% along with the overall Kappa statistics of 0.84 (Table 2). A corresponding indulgent of the classifications is attained through incremental investigation of the accuracy. The highest producer accuracy (i.e., error of omission) was calculated for the waterlogged areas and salt pan. This informs that the number of pixel for the waterlogged and salt pan correctly classified as a percentage of the total number of pixels. Consequently, the user accuracy regulates the consistency of the classification output with the ground reality (Patel and Kaushal, 2010). The maximum user accuracy (i.e., error of commission) was calculated for the coastal sand tidal salt marsh. The lowest producer accuracy was calculated for the coastal swamps (66.67%). The lowest user accuracy was calculated for the salt pan and coastal swamps (80%). This method enhances significant efficacy to the output classification.

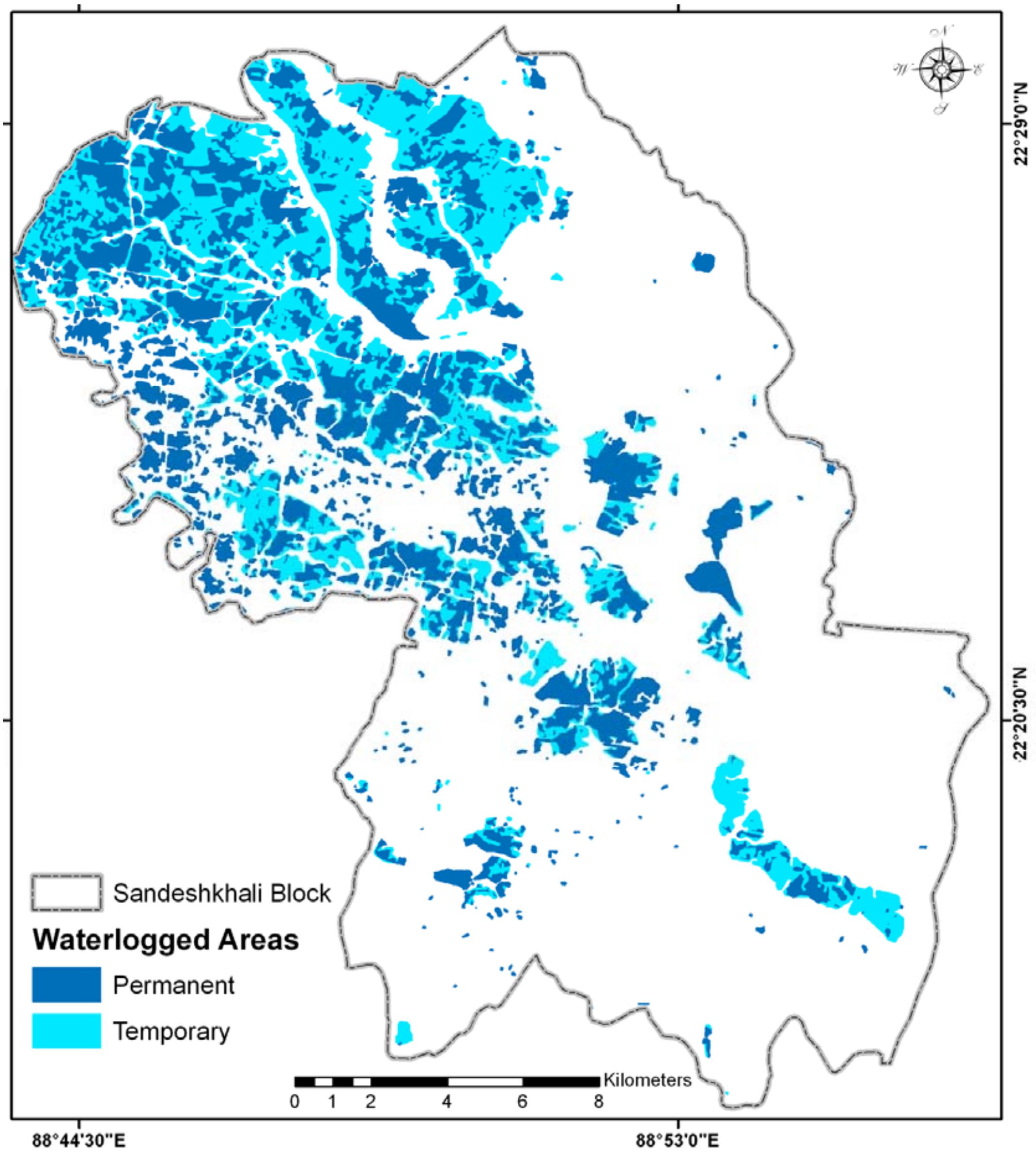

Fig. 4: Spatial aspect of seasonal waterlogged areas of Sandeshkhali block, North 24 Pargana district, West Bengal (India)

Accordingly, the observed decrease in the size of productive land area within the coastal regulatory zones is a fact. Salinisation, erosion and submergence of beaches/mud flats and artificial embankments due to the erosion-accretion process are also linked with sea level rise (Pavithran et al., 2014). Post partition refugee influx from erstwhile East Pakistan (currently Bangladesh), proliferation of aquaculture farms at the expense of natural mangrove forests and other anthropogenic activities leading to large scale reclamation of natural mangrove forests are all causing further environmental stress. The infrared wavelength bands are much more convenient and useful compared to the visual bands, which can be misleading for water mapping. The amalgamation of mixed pixel and high turbidity limit the usage of a single near-infrared band to categorize the water bodies.

5. Conclusion

Satellite data have become valuable tools in studying the spatial extent of degraded lands and also for monitoring the spatial changes in temporal domain. The methodologies can be used to extract precise and timely information on different aspects of degraded lands in a cost effective manner on operational basis. The significance of employing geospatial technology to achieve such tasks cannot be over emphasized. We have a battery of satellites for incessant supply of data for us to make proper decision making on unutilized as well as under-utilized land / soil resources. Timely procurement and processing of data on suitable temporal basis with the aid of a GIS platform can deliver a cost-effective method to manage areas of rapid wasteland changes.

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Author Biographies

Gouri Sankar Bhunia received his Ph.D. degree from the University of Calcutta, India, in 2015. He is working as a Manager at Aarvee Associates Architects, Engineers & Consultants Pvt Ltd, Hyderabad – 500 082, India. He had worked as a 'Resource Scientist' at Bihar Remote Sensing Application Centre, Patna (Bihar, India). Emai – rsgis6gouri@gmail.com

Pravat Kumar Shit received his Ph.D. degree in 2013 at Vidyasagar University in India. He is an Assistant Professor in the Department of Geography, Raja N. L. Khan Women's College, Gope Palace, Midnapore, West Bengal, India.. Email – Pravatgeo2007@gmail.com

Dilip Kumar Pal is a Professor and the Head of the Department of Surveying & Land Studies, The Papua New Guinea University of Technology, Private Mail Bag, Lae 411, Papua New Guinea. Email - dkpal200090@gmail.com