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Earth Observation and Geospatial techniques for Soil Salinity and Land Capability Assessment over Sundarban Bay of Bengal Coast, India

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Abstract: To guarantee food security and job creation of small scale farmers to commercial farmers, unproductive farms in the South 24 PGS, West Bengal need land reform program to be restructured and evaluated for agricultural productivity. This study established a potential role of remote sensing and GIS for identification and mapping of salinity zone and spatial planning of agricultural land over the Basanti and Gosaba Islands(808.314sq. km) of South 24 PGS. District of West Bengal. The primary data i.e. soil pH, Electrical Conductivity (EC) and Sodium Absorption ratio (SAR) were obtained from soil samples of various GCP (Ground Control Points) locations collected at 50 mts. intervals by handheld GPS from 0–100 cm depths. The secondary information is acquired from the remotely sensed satellite data (LANDSAT ETM^{+}) in different time scale and digital elevation model. The collected field samples were tested in the laboratory and were validated with Remote Sensing based digital indices analysisover the temporal satellite data to assess the potential changes due to over salinization.Soil physical properties such as texture, structure, depth and drainage condition is stored as attributes in a geographical soil database and linked with the soil map units. The thematic maps are integrated with climatic and terrain conditions of the area to produce land capability maps for paddy.

Finally, The weighted overlay analysis was performed to assign theweights according to the importance of parameters taken into account for salineareaidentification and mapping to segregate higher, moderate, lower salinity zonesover the study area.

Keywords: LANDSAT, GIS and Remote Sensing, kriging,soil properties, land capability

1. Introduction

Salt-affected soils are caused by excess accumulation of salts, typically most pronounced at the soil surface (Liersch et al., 2012). Salts can be transported to the soil surface by capillary transport from a salt laden water table and then accumulate due to evaporation. They can also be concentrated in soils due to human activity, for example the use of potassium as fertilizer, which can form sylvite, a naturally occurring salt (Bloem et al., 2009). As soil salinity increases, salt effects leads to degradation of soils and vegetation. Salinization is a process and results from (Astaraei et al., 2009):

- High levels of salt in the soils.
- Landscape features that allow salts to become mobile (movement of water table).
- Climatic trends that favor accumulation.
- Human activities such as land clearing activities.

Earth observation and Geo-spatial techniques is an effective tool to detect the salinity over the land by its Indices Based application and which intern reduces the conventional method of ground surveying and measurement (Katerji et.al, 1992). The application of digital indices like Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Normalised Difference Salinity Index (NDSI) with wavelength reflectance of soil in electromagnetic spectrum and calculation process the salinity can be measured by assessing vegetation health and soil over the study area (Saifeldeen Abd-Elwahed, 2005 and Avadhesh Kumar Koshal, 20l0). But in this research, the main parameters like soil pH, Electrical Conductivity (ds/m), Sodium Absorption Ratio of soil has to be considered (Indonesian Agency for Agricultural Research and Development, Indonesia, Fereydoun Keshavarzpour and Majid Rashidi, 2011). The ground truth verification is prime requirement (though time, cost increasing) by sampling and checking the indices analysis through Remote Sensing and image processing (Abbas et al., 2010). GIS also plays a pivotal role for various spatial analyses especially Weighted overlay technique and decision making.

To guarantee food security and job creation of small scale farmers to commercial farmers, unproductive farms in the South 24 Parganas, West Bengal need land reform program to be restructured and evaluated for agricultural productivity. However, this exercise requires the analysis of a large amount of spatial data. Using the conventional approach of land surveying will be time-consuming, laborious and costly, especially for environmentally sound (Sathish and Niranjana, 2010). Numerous land capability assessment techniques used are versions to the local settings of the Framework for Land Evaluation (FAO, 2007) and centre on the sternness of land restrictions connected to crops and land use (Desmet, et.al., 2009). The distinction between the classes is based on the rise of the costs for the reduction or elimination of these limitations (Madrau, et.al., 2009). Therefore, the produced information is incorporated in GIS to attain diverse thematic information for using in land assessment procedures. The use of remote sensing techniques has become increasingly important in describing a variety of satellite-derived data sets and their application to understand changes in the landscape (Al-Mashreki et al., 2010). With the advent of Remote Sensing, database generation became faster, cost effective and more reliable (Sathish and Niranjana, 2010). Since land capability analysis requires the use of different kinds of spatial and non-spatial data (soil, climate, land use, topography, etc.), the Geographic Information System (GIS) offers a flexible and powerful tool than conventional data processing systems, as it provides a means of taking large volumes of different data sets and manipulating and combining the data sets into new data sets which can be displayed in the form of thematic maps (Meghdadi and Kamkar, 2011).

The first and foremost aim of this research is to test the Physio-chemical properties of soil samples and determination of soil salinity based on pH, EC and SAR. Secondly, to develop a feasible approach that amalgamates remote sensing data with GIS techniques to determine the soil salinity zonation and Mapping based on several digital indices analyses with the temporal satellite images like, NDVI, SAVI, NDSI etc. further those are validated with the results of soil samples collected from field and finally, establish the potential role of remote sensing (RS) and GIS in spatial planning for agriculture in a communal land use setting, planning authorities with budgetary constraints. This study will also develop a methodology as a tool for land capability evaluation using remote sensing, GIS and geo-statistical techniques for communal areas, where the results can be duplicated in other geographical areas with similar biophysical conditions, to improve the accuracy of land evaluation. Land capability evaluation is an important procedure in agricultural planning, for purposes of detecting the environmental limits in sustainable land use planning. The ever increasing demands for increasing food grain production could be met through systematic survey of the soils, evaluating their potentials for wide range of land use options and formulating land use plans which are economically viable and socially acceptable (Du Plessis, 2003).

2. Scope of the present study

- Salt affected soils are widespread over the world especially in arid, semi-arid and some sub- humid regions. Soil salinity has been brought about by natural or human- induced processes and is a major environmental hazard. Crop growth reduction due to salinity is generally related to the soil in osmotic potential of the root zone.

- Recent advances in remote sensing technology have opened new vistas in inventory, characterization and monitoring of degraded lands. Remote sensing and GIS have been effectively used to study the dynamic behavior of salinity and waterlogging.
- Satellite imagery and false colour composites are visually interpreted to identify salt affected lands and locate their geographic position using the Global positioning system. Remote sensing and GIS software are utilized to analyze digital remote sensing data for the preparation of a digital database on salinization and the effect on cereal crops.
- In general remote sensing data can be used as a tool for discriminating between saline soils and non-saline soils on the dark soils that have high clay content but not with soils that have high sand content. The low soil salinity and early stages of salinization lower than 4 dS/m, is hard to be detected on bare soil using remote sensing.
- The use of Indices like salinity index and NDVI are the most challenging aspects of Remote Sensing Technology and analysis through weightage overlay also accounts for depending on other parameters on importance basis for spatial decision making in salinity zonation over any area.
- In classical technique researches on salinity were mainly based on the field sampling method and based on Soil pH, Electrical Conductivity, Sodium absorption ratio. It was hard to analyze and predict without salinity and required long time and economy.
- Remote Sensing and GIS technology with the integration of Field Surveying can be proved as the optimal decision making process for salinity zone identification and zonation and will save time, money, energy of the research work.
- On this basis faster decision can be obtain to propose policy or method to conserve the land of any area which is under continuous process of salinization.
- Assessment of land capability and potentiality for the agricultural land especially in paddy cultivation.

3. Study area

The study area is identified in the South 24 Parganas district of West Bengal State with its district headquarters in *Alipore*. It has the urban fringe of Kolkata on one side and the remote river-line villages in the *Sundarbans*. Agriculture, Industry and Pisciculture are all at their peak in the district. The study area *Gosaba* and *Basanti* blocks (South 24 Parganas) lies between 21°29′00″ N to 22°30′00″ N and 88°30′00″ E to 89°00′0″E with an areal extent of 808.314 sq.km is shown in Figure 1. *Gosaba* and *Basanti* are the main deltaic islands in the *Sundarban* region, bounded by the *Matala* and *Zilli* rivers / creeks and mangrove forest.

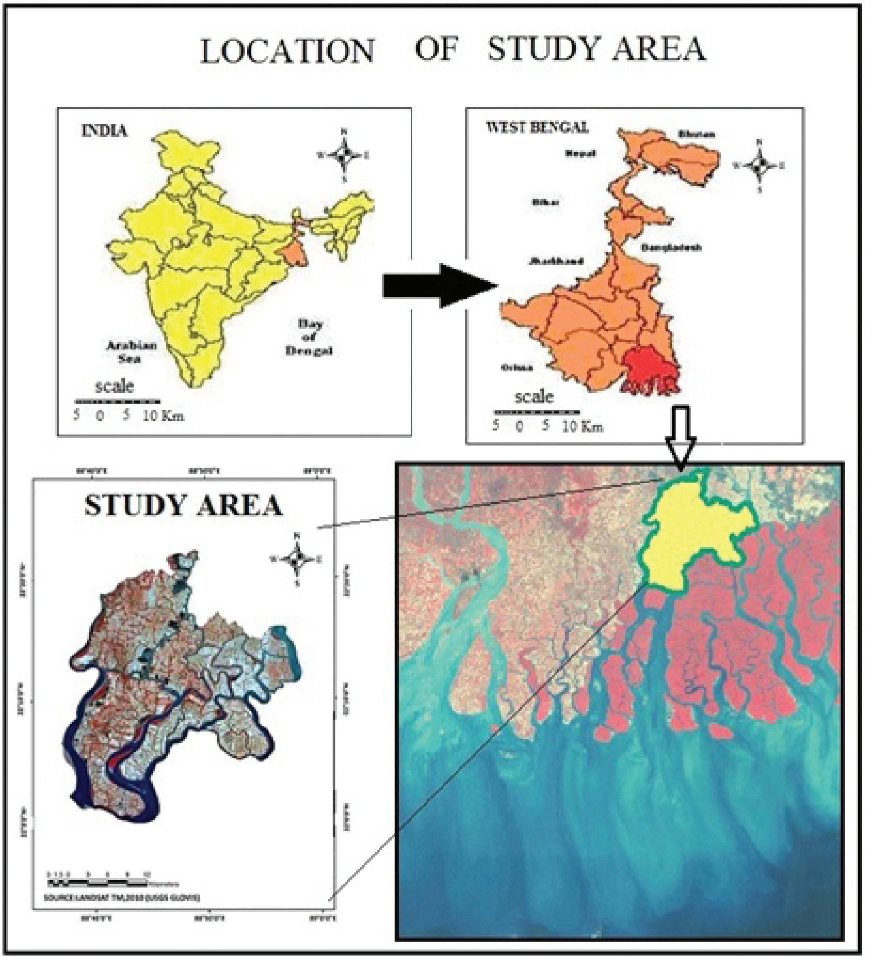

Fig. 1. Location map of study area

The geological formation of the Island is of comparatively recent origin. Many years back the whole was submerged under the sea. The formation with deposition occurred with recent changes of the main course of River *Ganga*. This was because of the result of neotectonic movement on Bengal Basin and an easterly tilt.

The main rivers *Matla* and innumerable creeks network are distinctive features in the two Island Branching tributaries of creek systems have a prefect pattern over the salt marshes. Meandering were identified in the study area stream network. All rivers have a southward course towards the sea. Tidal effect dominates over the eco-geography of the area. Two flow tides and two ebb tides outing within 24 hours with the tidal range 3-5 m and up to 8m in normal spring tide, inundating the whole of *Sundarbans* in varying depths.

In *Gosaba* and *Basanti* Island soil show sandy clay loam type. In the reclaimed areas soils are saline in nature clay loam and sandy loam textures were found in coastal marsh patches of island. The major soil textures are coarse loamy, fine loamy, sandy clay, silty clay, silty loam. The hydrological group A, B, C is predominating over the area.

The land cover type shows by dense forest, mangrove forest, marshy land, salt pan, natural drainage over the areas and land use types are agricultural land, fallow land.

The average maximum and minimum temperature is 34˚C and 20˚C respectively. The monsoon lasts from mid June to mid – September. Storm which sometimes develop into cyclones are common during the month October.

Rainfall is the primary source of water for plant growth and is readily available data. Annual rainfall data for the period 1975 to 2010 were used to analyse annual rainfall discharges for the farm (Figure 2).

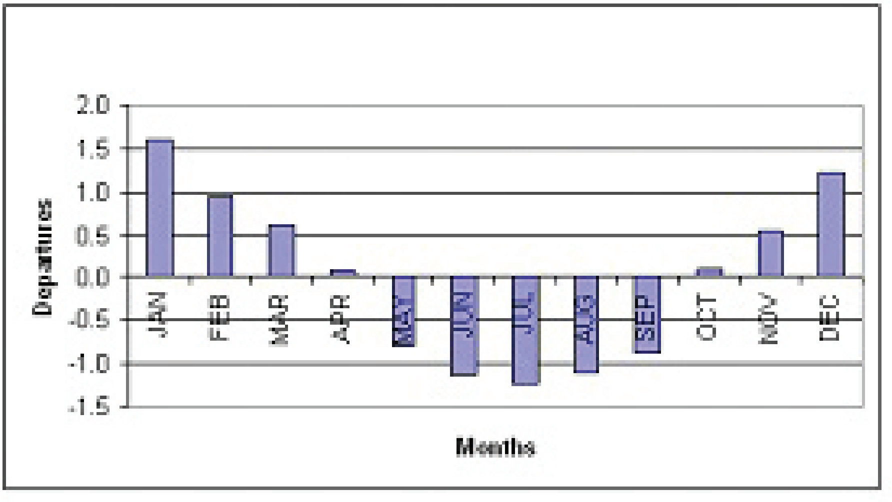

Fig. 2. Monthly rainfall discharge for the study area

The permanent features over the study area were shown through the base map (Figure 3). It is consisting of Administrative Boundary, Road Network and Drainage (*Matla river, Bidya River*) along with the major locations. The total geographical area within the boundary 808.314 sq. km was obtained through GIS software.

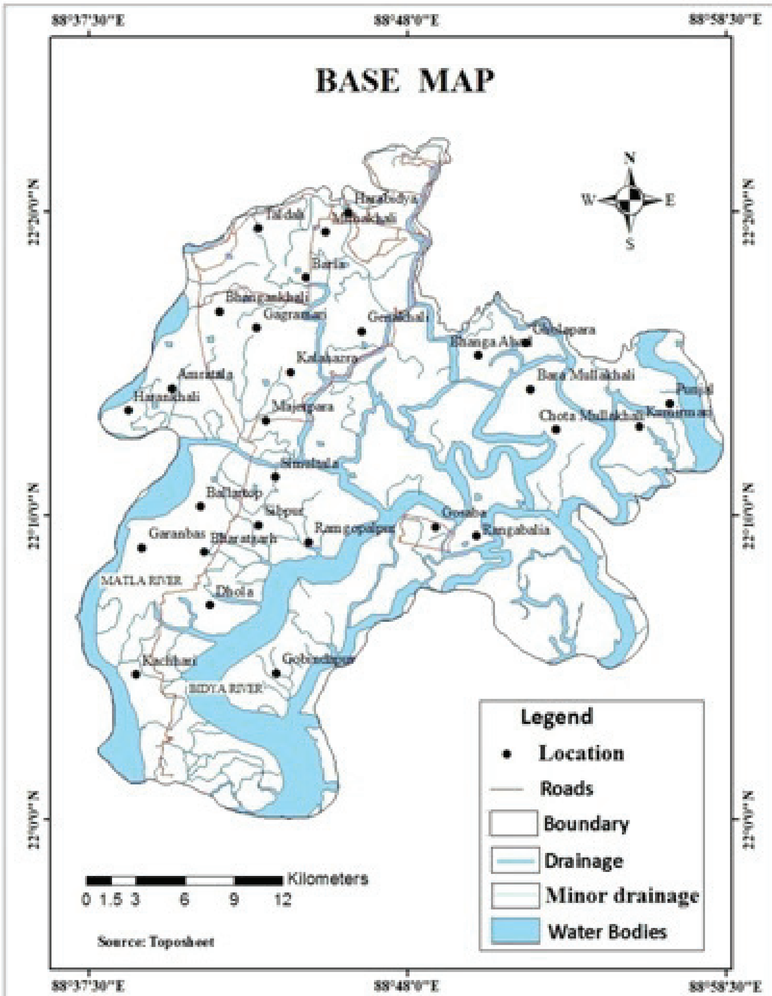

Fig. 3. Base map of the study area

4. Materials and Methods

4.1. Remote Sensing data

Temporal satellite data of LANDSAT MSS, TM and ETM$^+$for the year of 1975, 2000 and 2010 with spatial resolution of 57 m, 30 m and 30 m. Respectively were obtained from USGS GLOVIS (Figure 4) and taken in the rainy season as natural vegetation is in prime leaf condition, which is ideal for computation of representative NDVI values. The satellite images were obtained at a preprocessing level (Level IA) at which radiometric and geometric corrections were required. The images underwent atmospheric correction by computing the reflectance at the Top of the Atmosphere (TOA) for each image, in order to account for the variation in the relative positions between the sun, the earth and the satellite (Updike and Comp, 2010). Converting the Digital Numbers (DN) to Top of Atmosphere reflectance (ρ) is done using Equation 1 and 2 (Clark, et al., 2010). Radiance (Lλ) values (expressed as W $m^{-2}sr^{-1}\mu m^{-1}$) is computed using Equation 1, with gain (G) and offset (B) values that were supplied in the image metadata. Then reflectance (ρ) values were computed for the two bands using Equation (2).

$$\text{Radiance } (L\lambda) = \frac{DN}{G} + B \tag{1}$$

$$\rho = \pi L\lambda d^2 / (Esun_\lambda \cos \theta_S) \tag{2}$$

Where, ρ is the reflectance, L λ is the spectral radiance at the sensor's aperture (W $m^{-2}sr^{-1}\mu m^{-1}$), d is the date corrected earth – sun distance (astronomical miles) Esunλ is the ETM^+ sensor and band specific equivalent solar irradiance and θ s is the solar zenith angle.

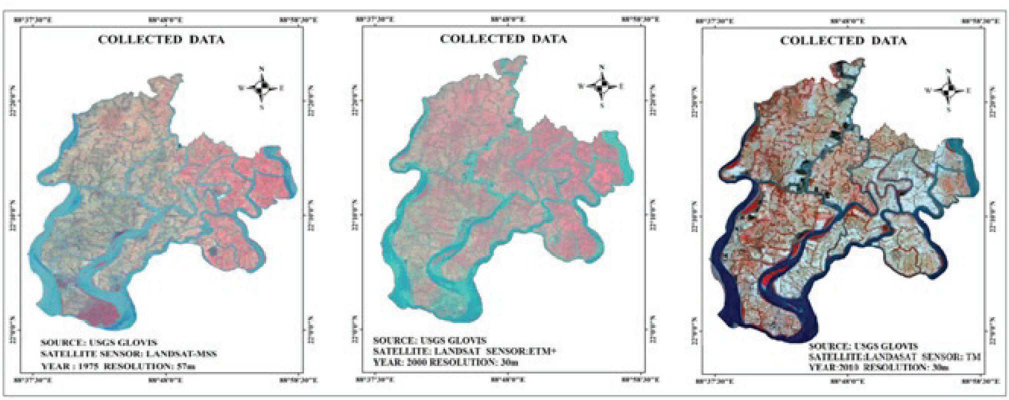

Fig. 4. Landsat satellite data in the years 1975, 2000 and 2010 of the study area

To confirm the pixel grids and remove any geometric distortions, the images were registered to a UTM map projection using a nearest neighbour resampling routine (Lillesand et al., 2008). Based upon thirty-six ground control points collected from topographical map (1:50,000) and field work using a hand-held global positioning system with an accuracy of 4 m, image to image registration has been done and a sub-pixel root mean square error was achieved for each image. A subset of the study area was created and this was followed NDVI calculation and identification of training sites. Supervised Classification of remote sensing data was done through the use of a maximum likelihood algorithm classification method. The advantage of the maximum likelihood algorithm is that it takes the variability of the classes into account by using the covariance matrix (Lillesand et al, 2008). The training sets were chosen on the basis of field knowledge of landuses and the various LULC(Land use/ Land cover) types identified in the image scene like dense vegetation, cropland, built-up land, water, and bare soil. The Change of areas in land use and land cover were viewed from raster attribute data. The dominant effects of the salinity over the area and land conversion were analyzed. A 3*3 spatial convolution filter was used to clean the classified images to the generalization of the study area. To assess the accuracy of the classification process, high resolution field data, Google Earth image and 1:50,000 topographic maps of 2014 were used for validation.

4.2. Soil data collection

Field work was undertaken between March and May, to determine the location of representative sites for the main land-cover types in the image scene and to collect soil samples Soil auger bores was excavated to 1 m depth (or to bedrock) to identify soil fertility, soil depth and texture, an excavation to 1 m soil profile depth is satisfactory for most soils (Soil survey manual, 1993). Samples were taken using soil auger bores to determine physical and chemical parameters related to soil classification (Indian standard) (Soil survey manual, 1993). Representative soil samples have been collected and analyzed using the soil survey laboratory methods manually. Soil textural classification map (IS) has been collected as a reference from National Bureau of Soil Science – Landuse Planning (NBSS-LUP). The collected soil samples are tested in the laboratory to derive pH, EC (Electrical conductivity) and SAR (Sodium absorption ratio) (Bannari, 2009).

Geo-statistical interpolation using Kriging tool was used to classify soil properties within the sampled locations in the ArcGIS software. The interpolation predictions from Kriging are relatively accurate compared to other interpolation techniques like Inverse Distance Weighting (Gotway et.al., 1996). Kriging depends upon a semi-variogram which considers spatial relationship and distance.

The semi-variogram ϒ(h) is described in Equation 3 (Kerry et al., 2010).

$$\Upsilon(h) = \frac{1}{2\,N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \quad (3)$$

Where, $z(x_i)$ represents the measured value of the soil property at location x_i, ϒ(h) is the semi-variogram for a lag distance h between observations $z(x_i)$ and $z(x_i + h)$, and $N(h)$ is the number of data pairs separated by a lag distance equal to h.

4.3. Other ancillary data collection

Block map from local SDM office, Monthly average Rainfall and temperature data (1975-2010) from Indian Meteorological Department (IMD), Kolkata, rainfall discharge rate from IMD (2000-2010), socio-economic information (1975-2010) from Census of India, 2001-2011, seasonal crop information (2000-2010) from local survey and some field photographs (2010) also have been collected as ancillary and associated information of the study area which were very useful for further analyses and mapping.

4.4. Indices Analysis

Indices are the models which deals with the spectral reflectance of the spatial features in various wavelength of electromagnetic spectrum. It is the modernized technique to analyze the vegetation health, condition, soil condition through various reflectance over wavelength.

4.4.1. Normalized Difference Vegetation Index(NDVI)

This index deals with the Reflectance of green cover in Near Infrared Band (.7-1.4 μm) based on structure and water content present in the cover and absorption of Red band (.6-.7 μm) due to presence of chlorophyll in the vegetation (Lillesand et al. 2008). The vegetation health can be optimally analyzed in good or poor condition by NDVI method (Equation 4).

$$\text{NDVI} = (\text{NIR[Near Infrared]} - \text{RED})/(\text{NIR[Near Infrared]} + \text{RED}) \quad \text{Eq. (4)}$$

(+1 = Good condition of vegetation health)
(-1 = Poor Condition in Vegetation Health)
NDVI is a powerful indicator to monitor the vegetation cover of wide areas, It provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. Tucker first suggested NDVI in 1979 as an index of vegetation health and density (Thenkabail et al., 2004) and it has been considered as the most important index for mapping of soil salinity. NDVI is a nonlinear function that varies between -1 and +1 and values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation (FEWSnet). NDVI is good indicator of green biomass, leaf area index and patterns of production (Thenkabail et al., 2004).

4.4.2. Soil Adjusted Vegetation Index(SAVI)

This index accounts for minimizing the effect of soil in acquiring 100% reflectance from vegetation. It is effective in analyzing vegetation and soil condition by incorporating L, as the correction factor to improve on NDVI. If L = 0 then NDVI = SAVI (SaifeldeenAbd-Elwahed,2005; Avadhesh Kumar Koshal, 20l0). It is shown in the Equation 5.

$$SAVI = \{(NIR - RED)*(1+L)\} / (NIR+RED+L) \quad (5)$$

In areas where vegetative cover is low (i.e., < 40%) and the soil surface is exposed, the reflectance of light in the red and near-infrared spectra can influence vegetation index values. This is especially problematic when comparisons are being made across different soil types that may reflect different amounts of light in the red and near infrared wavelengths (i.e., soils with different brightness values). The soil-adjusted vegetation index was developed as a modification of the Normalized Difference Vegetation Index to correct for the influence of soil brightness when vegetative cover is low (Richardson and Everitt, 1992; Lyon et al., 1998; Senseman et al., 1996).

Where, NIR is the reflectance value of the near infrared band, RED is reflectance of the red band, and L is the soil brightness correction factor. The value of L varies by the amount or cover of green vegetation: in very high vegetation regions, L=0; and in areas with no green vegetation, L=1. Generally, an L=0.5 works well in most situations and is the default value used. The SAVI is structured similar to the NDVI but with the addition of a ‘soil brightness correction factor (L)’.

4.4.3. Normalized Difference Salinity Index (NDSI)

This index also deals with the NIR band and Red band in assessing salinity condition of salt affected area (Avadhesh Kumar Koshal, 20l0). The brightness values in white encrustation can be analyzed as salt encrusted land. NDSI can be derived by Equation 6.

$$NDSI = (RED - NIR) / (RED+NIR) \quad (6)$$

4.5. Integration of GIS and Remote Sensing

4.5.1. Digitization

It is the method of converting analog data to digital form (Kang-tsung Chang, 2009). The digitization of boundary of the study area along with drainage, water bodies, Road network were followed in ARC GIS 9.3 software by creation of Personal

Geodatabase with assigning the coordinate system and creation of feature dataset and feature classes.

4.5.2. Overlay Analysis Method

It is the method of overlaying two input features of same geographical location to achieve new output (Kang-tsung Chang, 2009). Through this method the NDSI map and the measured pH, EC values with the Collected GCP points through GPS were overlaid to verify whether the remote sensing analysis due to salinity impact and measured salinity from ground sampling truth are matching. The accuracy of the work can be assessed and high, moderate, low zones of salinity were be achieved.

4.5.3. Weighted Overlay Analysis

It is a simple and stratified method for combining analysis of different themes. The weights are assigned according to the importance of themes with respect to the objective (Kang-tsung Chang, 2009). The weightage of each parameter (SAVI, NDSI, Landuse Classes) were decided on the basis on ranges of the maximum and minimum values of each parameter. Total weightage were divided into different zones of salinity like high, moderate, poor. Finally, from the weighted overlay analysis of 1975, 2000, 2010 salinity identification and zonation was performed at the final stage of the research work.

4.6. Land capability assessment

The obtained data was imported in a geo-database, the spatial analyst function in ArcGIS 9.3 was used to create the thematic layers and analysed using weighted overlay analysis, to produce the land capability map. Weight assignment is determined by consulting the opinions of the Department of Agriculture literature. Using the weighted aggregation method in ArcGIS, weighting is carried out for each thematic layer and. In this method, the total weights of the final integrated polygons are derived as sums or products of the weights assigned to the different layers, according to their capability. The equation 7 used in a GIS for the assessment of land suitability for agricultural purposes is:

$$LSP = 0.2(LU)_{i=1\text{-}4} + 0.1(SL)_{i=1\text{-}4} + 0.2(D)_{i=1\text{-}3} + 0.2(T)_{i=1\text{-}5} + 0.2(pH)_{i=1\text{-}312} + 0.05(C)_{i=1\text{-}3} + 0.05(DR)_{i=1\text{-}3} \quad (7)$$

Where, LSP is the land suitability index, LU is the land use/land cover variable (with classes 1–4), SL indicates slope on (with classes 1–4), D indicates depth factor (with classes 1–3), pH indicates soil pH (with classes 1–3), T indicates texture (with classes 1–5), C indicates clay percentage (classes 1–3) and DR indicates drainage (with classes 1–3). Summer field crop are chosen as promising crops as they are better suited for the climatic conditions of study area (Afework Mekeberiaw, 2009). Knowledge on the growth conditions of summer crops were obtained from local researchers, in combination with information from the literature (Department of Agriculture, Forestry and Fisheries, 2010).The detail methodology and work flow is shown in the Figure 5.

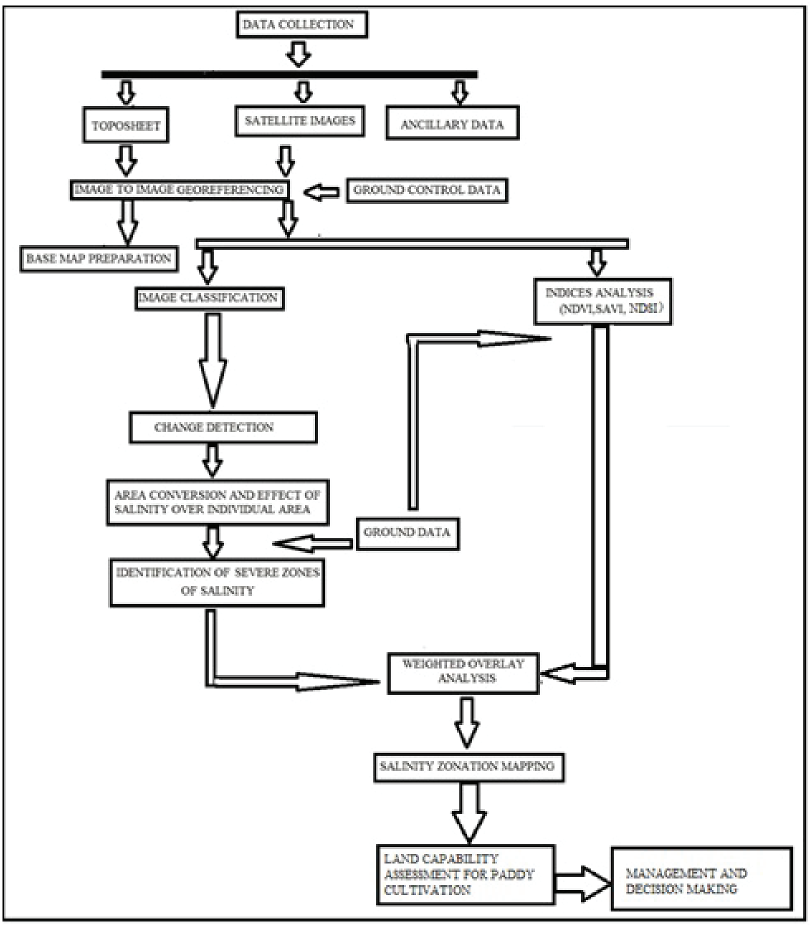

Fig. 5. Work flow diagram

5. Results and Discussion

The following results were obtained at the end of theresearch.The analytical works were carried out in Erdas Imagine, ENVI and Arc GIS software.

5.1. Land use / Land Cover Classification

Figure 6(a), (b) and (c) show the land use and land cover classification of the entire study area in different time scale, which were done in Erdas Imagine Software through supervised classification technique using maximum likelihood classifier algorithm and by assigning training sets, the different classes with spatial extension and different tonal variation were achieved. The classification of each satellite images were carried out with almost 92.7% accuracy and it is validated with collected GCP from ground truth. The different classes identified like, natural dense forests, mangrove forests, salt pan, marshy land, water bodies, agricultural land, fellow land over the study area.

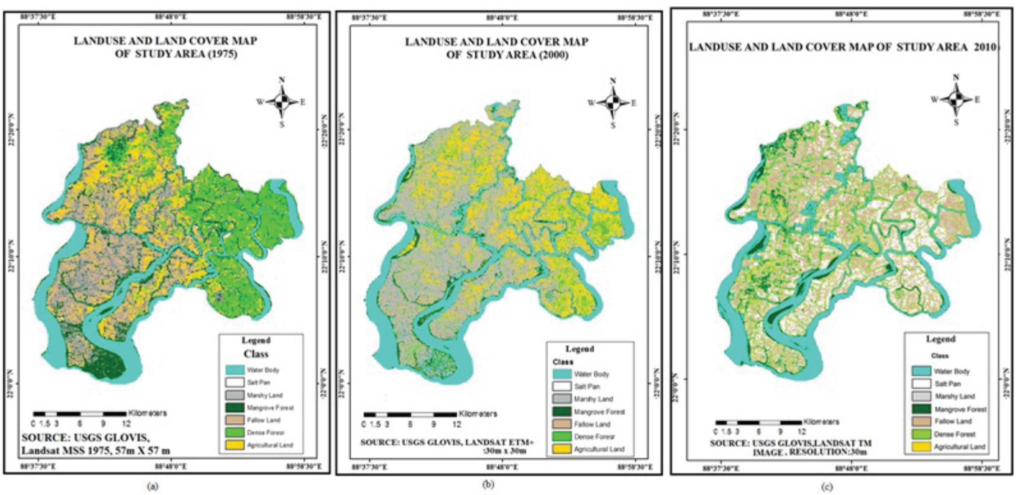

Fig. 6. Land use and land cover classification over temporal satellite images of study area (a) 1975, (b) 2000, (c) 2005

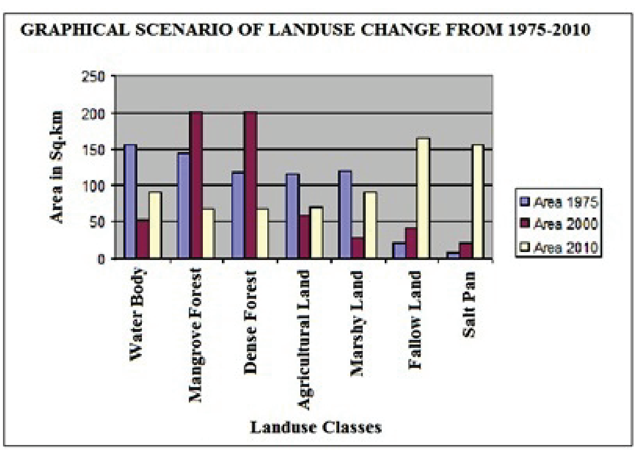

Fig. 7. Statistics of land use and land cover, 1975-2010

The graphical representation (Figure 7) of the areal cover of LULC were generated through classification process which is showing individual areas of that class. The natural land like water body has changed over the years and decreased over the space. Mangrove Forest has decreased immensely and estimated from 145 sq.km to 66.51 sq.km over the three decades. Dense forest has decreased from 117.36 sq.km to 67.42 sq.km whereas, the fallow land has increased from 19.87 to 163.61 sq.km. Salt Pan also has increased from 6.52 sq.km to 155.63 sq.km, Agricultural land has decreased from 115.84 sq.km to 70.6 sq.km.

The scenario show the changes over the area due to impact of over salinization as well as human induced processes. The Mangrove, other forests area and agricultural land are reduced from 1975 to 2010 whereas, salt encrusted area, fallow land were increased from 1975 to 2010.

The agricultural lands were converted to fallow land immensely due to over fertilization by human induced method. The forest cover decreased due to salinity as well as the forest clearing.

5.2. Soil Physical Properties

Moderately well drained soil covers 25.4% of the study area, Figure 8(a). The soil map of the study area shows loamy, silty, clay types of soil. The zonation were done on Arc GIS through kriging and separating each soil type by its attribute with soil type data acquired from NBSS-LUP (National Bureau of Soil Survey and Land Use Planning). It is the result of the disintegration of the upper part of the earth under the natural forces. The major soil type which has occupied 362.64 sq.km of the area is Fine Loamy soil and lowest soil distribution is 50.64 sq.km is covered by Silty Loam soil. Sandy texture has somewhat excessive drainage class. Water is rapidly lost as the soil are pervious and can be subjective to runoff, the soils are however free from mottling related to wetness (Fletcher and Veteman, 2014). In silty loam soils, silt particles is concentrated but contains moderate clay and other sediments to provide some structure. loamy structure is able to quickly drain excess water but this results inability to hold significant amounts of water or nutrients. The textural classes of the soils in the study area were re-classified into hydrologic soil groups (HSG's) as depicted in Table 1which indicates the minimum rate of infiltration obtained for bare soil after prolonged wetting. There are three soil HSG (Hydrological soil group) namely A, B, and D are the elements used in determining runoff curve numbers. The soil group A is occupying major area as 362.64 sq.km, B is occupying minimum area of 50.64 sq.km and D is distributed of 177.9 sq.km area. A group is dominating group in which the high infiltration zones will indicate the water logging. Surface application of organic manures to sandy soils does not last so the manure should be dug deeper into the soil or a carpet-like layer spread of not less than one centimetre thick, which will improve water storage, biological activity, nutrient status and increase yields (FAO, 2007). Due to high percentage of sandy and loamy soils, high proportion of clay fraction is less than 19% (Figure 8(b)).

Table 1. Relationship of Soil Texture and Hydrological Group

Hydrological Group	Soil Texture
A	Fine Loam, Coarse Loam
B	Silt Loam
D	Silty Clay

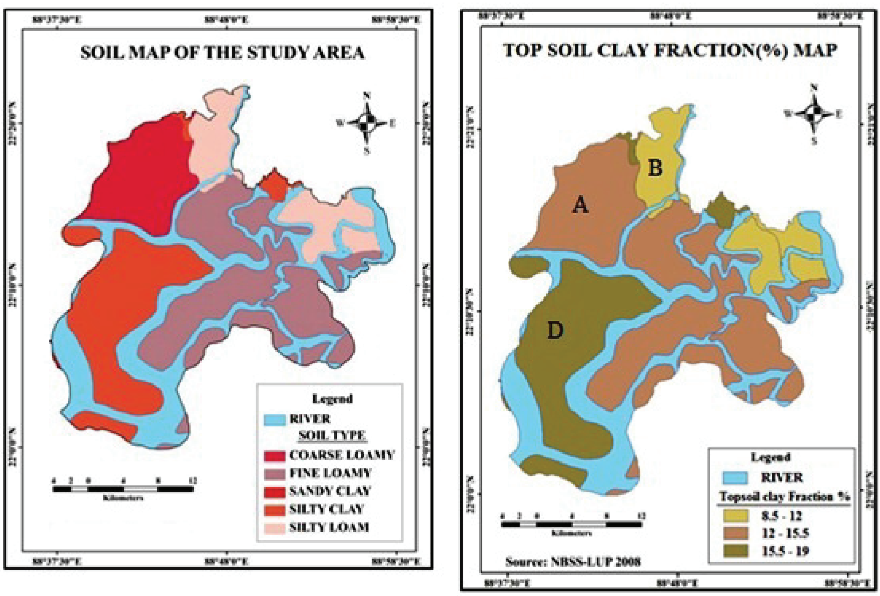

Fig. 8. Soil texture classification (Indian standard) and drainage (a) and Top soil cay fraction with Hydrological Soil Group (b)

5.3. Chemical properties of soil

The sum of 28 soil samples are collected in 50 mts. interval over the entire study area with the help of handheld GPS (Global Positioning System) and tested in the laboratory to derive the parameters like Ph, Electrical Conductivity (ds/m) and sodium absorption ratio (Table 2) to check the salinity status of the study area according to Indian Standard (Salinity= pH <8.5, EC>4, SAR<13 (saline soil) and >13 (Alkaline soil).

Table 2. Chemical properties of collected soil samples along with their location point by GPS

Sr. No	Places	Longitude	Latitude	pH	EC	SAR
1	Majerpara	88.728365	22.201063	5.3	0.71	40.1
2	Simultala	88.755038	22.191918	7.98	0.91	194.2
3	Ramgopalpur	88.729508	22.133235	6.21	0.34	19.73
4	Gatkhali	88.679971	22.100846	7.98	1.84	273.6
5	BairamChowranghee	88.664728	22.044068	8.1	0.13	9.73
6	Jharkhali1	88.679971	22.04826	7.5	4.62	264
7	Jharkhali2	88.719981	22.023873	7.42	4.03	298.6
8	Jharkhali3	88.785142	22.322239	6.32	0.88	17.93
9	Baria	88.750847	22.303948	7.62	1.72	199
10	Arampur	88.778283	22.188488	4.5	1.02	68.3
11	Gobindopur	88.73408	22.098178	4.52	1.06	42.6
12	Chandimor	88.825915	22.222783	5.32	1.72	241.4
13	Bara Mullakhali	88.883073	22.248314	5.02	0.34	22.44
14	Jyotiramghat	88.87469	22.19268	4.02	2.06	44.8
15	Jyotiramghat2	88.913938	22.175151	5.2	1.66	200.1
16	Chotamullakhali	88.925751	22.209446	8.12	1.5	253
17	Kumarmari	88.941755	22.217067	8.2	1.89	317.5
18	Punjal	88.923465	22.22507	5.2	1.02	190.2
19	Gosaba	88.899077	22.107324	6.04	4.22	253.8
20	Gosaba2	88.625853	22.090979	5.2	1.52	190.1
21	Gosaba3	88.674613	22.177216	8.5	0.22	310.2
22	Harankhali	88.641166	22.220012	6.66	3.12	30.2
23	Kumarmari2	88.746746	22.339052	8.2	1.09	250.5
24	Harabaidya	88.797521	22.360409	4.04	1.01	50.1
25	Harabaidya2	88.817267	22.369275	5.24	0.88	195.6
26	Joytiramghat3	88.958007	22.196398	6.88	1.2	40.9
27	Punjal2	88.948335	22.243143	6.43	2.44	36.2
28	Gosaba4	88.703325	22.01018	5.22	0.67	180.2

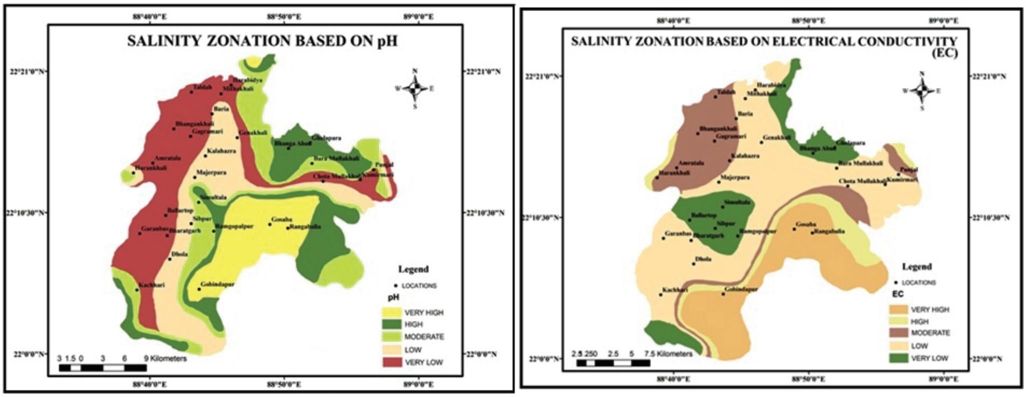

Fig. 9. The salinity status according to pH values (a) and EC values (b)

According to the derived pH and EC values all over the study area, the zonation (Figure 9a and 9b) has been developed by kriging method in Arc GIS software to check the overall distribution of salinity on the basis of very high, high, moderate, low, very low zones based on soil pH condition(Figure 9.a). *Gosaba, Rangabelia, Gobindapur, Bhanga Abad, Gholpara* areas are the indicator of very high and higher zones and the pH values ranges between 4–5. The moderate salinity occupied near *Sibpur, Baramurakhali, Simultala* between 5–6.The low and very low salinity areas were *Kalhabazar, Majerpara, Dhola, Amrata, Bhangankhali, Taldah* i.e, >7 (Figure 9.a).

Electrical Conductivity (EC) is another important parameter to check the salinity status. According to the laboratory tested values the zonation of EC (Figure 9.b) was done as same like pH. The very high and high accumulation of EC values were found near *Gobindapur, Rangabelia, Gosaba*. Moderate zones were under *Bhangankhali, Amratala, Taldah* areas and very low and low concentration were found near *Kachari, Simultala, Baramurakhali, Chotamurakhali, Harabidya*.

5.4. Waterlogged Condition Analysis

Considering the slope and the land surface condition, excess amount of water accumulation may leads to salinization process. The SRTM (Shuttle RADAR Topographic Mission) data 2010 with 90m spatial resolution were analysed in virtual GIS(3D) on the basis of elevation variation over the entire study area (Figure 10). The highest elevation is 21m from M.S.L. Mean sea Level). From the analysis of topographical data it has identified the north eastern part near *Punjal, Kumaramari, Rangabalia* are the most inundated part by the coastal saline water.So it is assumed, due impact of cyclone (Aila) in the year of 2009 the water got accumulated in the lower elevated areas and responsible for oversalinization over certain areas (Figure 10).

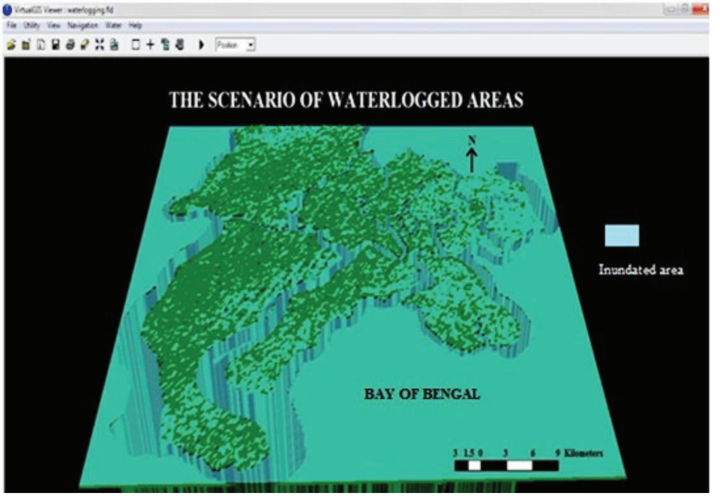

Fig. 10. Coastal saline water accumulation of the study area in 2010

The data were standardized with respect to the long term precipitation mean and summed up to attain annual rainfall. The months of October to April are generally used as growing periods of crops, this is because these months have above normal discharges. The temperatures also follow the same pattern.

5.5. Normalized Difference Vegetation Index (NDVI)

The NDVI was used with the Landsat Multispectral Scanner (MSS,1975), Landasat TM (2010), Landsat ETM(2000) and made use of channels 3 (Red) and 4 (NIR). The NDVI identified the photosynthetic affinity or 'greenness' of the vegetation through there flective proprieties of the chlorophyll and mesophyll layers within the plants in the NIR and red part of the EM spectrum. The NDVI value ranges from +1 (high value, healthy condition of vegetation) to -1(low value, poor condition of vegetation) and between +1 to -1 (denotes moderate condition of vegetation).In the year of 1975, very high, high values of NDVI was prevailing over the north eastern part near *Punjal, Kumaramari, Harabidya* whereas moderate condition was visible over western and southern and as well as on central part of *Ballartop, Kachchari* areas and low condition and very low was taken over mainly water bodies (Figure 11(a)). In the year of 2000, again the very high and high condition was seen near eastern and northern parts. But mostly the moderate condition of vegetation increased by the years and low ,very low condition has taken by water bodies (Figure 11(b)) where reflectivity is less. In the year of 2010, low and very low condition was visible in the north eastern and northern part (Figure 11(c)). The NDVI analysis at different time scale on the satellite images indicate the condition of vegetation got detrained from the year 1975–2010.

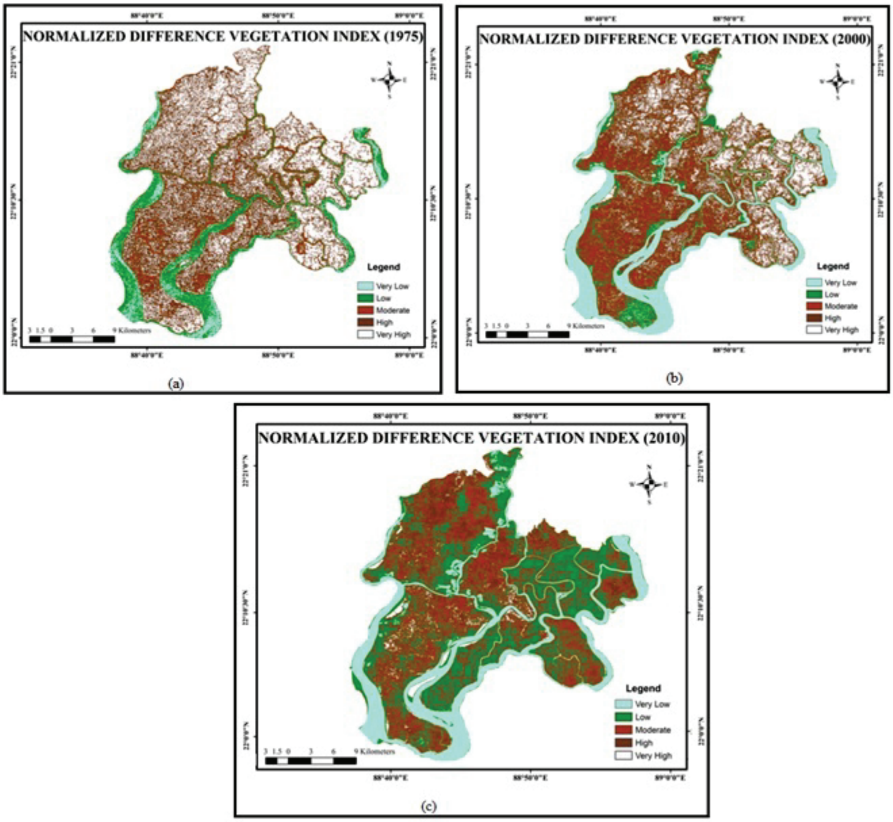

Fig. 11. NDVI of the year (a) 1975, (b) 2000 and (c) 2010

5.6. Soil Adjusted Vegetation Index (SAVI)

SAVI index were generated by designing model in Erdas Imagine software to eliminate the reflectance of soil background and to acquire 100% vegetation reflectivity. L the correction factor (0.5) was incorporated in the NDVI standardized formula to improve the result. The output of SAVI is shown in the figure 12(a), (b) and (c). On the basis of SAVI, the study area was segregated with very high, high, moderate, low, very low condition.

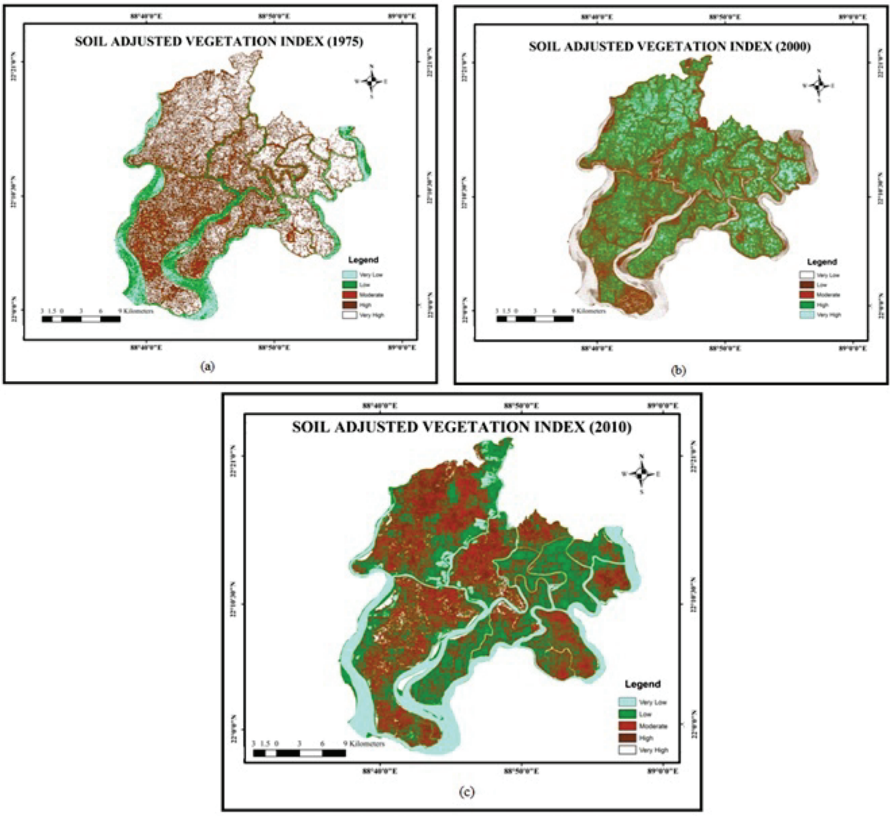

Fig. 12. SAVi of the year (a) 1975, (b) 2000, (c) 2010

5.7. Normalized Difference Salinity Index (NDSI)

NDSI were generated considering the standardized accepted formula of NDSI to check the fluctuation in salinity condition from the year 1975 to 2010 by designing model in Erdas Imagine Software and value ranges between +1(highly saline condition) to -1(low saline condition). Results shown in Figure 13(a), (b) and (c) as very low, low, moderate, high and very high.

In the year of 1975, the very low salinity zones were mostly visible in the north east part of the study area according to the NDSI result and the low saline condition persisted all over the area except water bodies which showed the very high and high saline water. Moderate salinity condition were scattered all over the area (Figure 13 (a)). Whereas, the NDSI of 2000 (Figure 13(b)) indicates very low and low amount of saline conditions over the water surfaces and very high and high conditions in the north east and central and northern part and moderate salinity zones were visible over the mangrove patches in islands. In the year of 2010, immense changes were found in NDSI value. Water in the riverine systems were occupied by very high saline condition and huge amount of land surface were engulfed by the high salinity and moderate condition also prevailed near central and northern and western part (Figure 13(c)). Whereas, the areas for very low and low saline land surface got decreased. The change in increasing of salinity at an alarming rate occurred from 1975-2010 due to devastating act of cyclone (Aila) in the year 2009 as well as other small cyclonic activities during 1975-1999 which are responsible for dynamism over the coastal island like *Basanti,Gosaba* in Sundarban region of West Bengal.

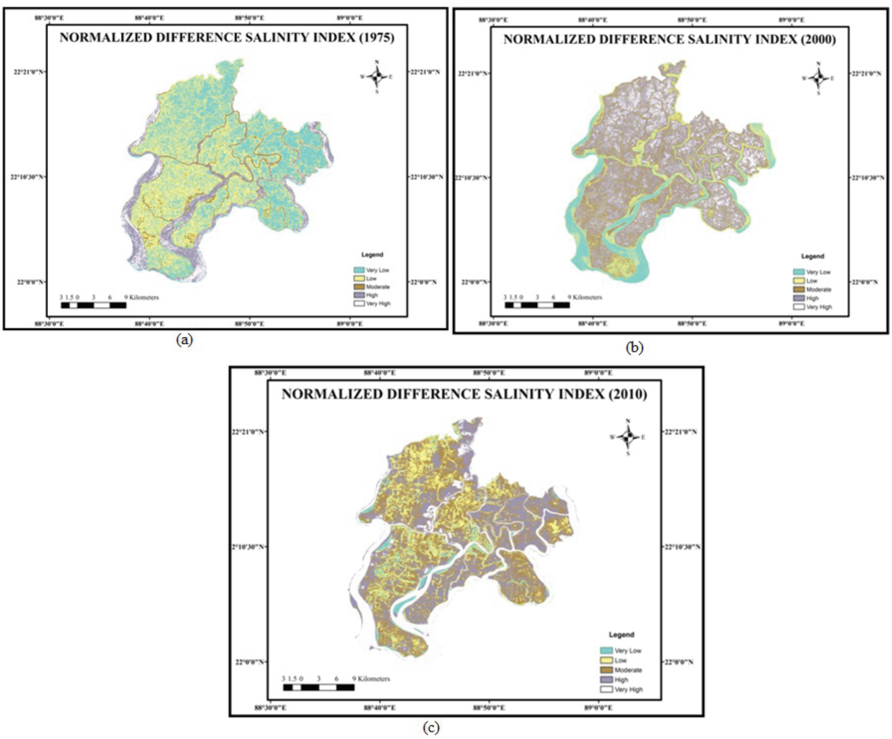

Fig. 13. NDSI map of (a) 1975, (b) 2000, (c) 2010

5.8. Correlation Between pH and NDSI

A correlation between 28 ground sampled pH data and software generated average NDSI values from 1975 to 2010 (shown in Figure 13) were derived through regression analysis to validate the salinity condition based on NDSI over the study area. Figure 15 shows straight line equation and trend line and the R^2 value came 0.331. The root mean square value shows approximation of data points as well as the normal R^2 value (between 0–1). Wherever, NDSI value is high (+1) and the pH value is low (<8.2). It indicates the high salinity and the two variables are well correlated. It predicted the salinity with high accuracy (Figure 14).

Since the acquired pH values from soil sample testing showed high accuracy in prediction of salinity. The pH values were overlaid (Figure 15) on the NDSI 2010 to check the accuracy of remote sensing method of salinity zone identification through indices based analysis. Wherever very high and high zones of NDSI (near+1) were found pH values also showed between 4–5 and moderate NDSI matched with moderate pH values between 5–6 and low and very low values for pH ranged from 7 to >8 which matched the low NDSI (-1) values and indicated low saline zones. So it can be concluded that, empirical analysis matched with the remote sensing analysis for salinity zone prediction and identification.

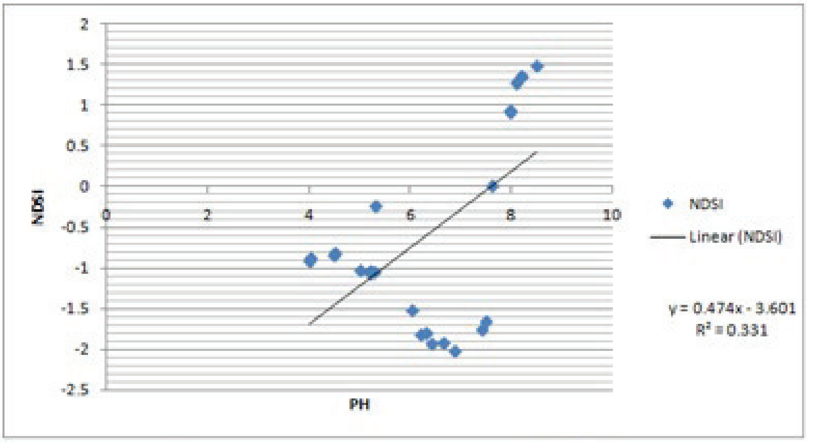

Fig. 14. Correlation between pH and NDSI

The farm allows for the cultivation of paddy of maximum 61.4% under highly to moderately suitable (Figure 15). The soil in these areas are characterised by favourable physical properties such as free from restrictive layers (hardpan) and a good effective depth of 100 cm. The soils also have sufficient and balanced quantities of plant nutrients and chemical properties. Highly suitable and Marginally suitability land for paddy cultivation accounts summation of 35% of the farm, the land has limitations that can be severe if used without proper soil management as sustained application will reduce productivity. Moderate suitability accounts 15% of the farm and Marginally not suitable (N1) and permanently not suitable (N2) land accounts summation of 49% of the farm. The soils in N1 and N2 have high pH concentration and not at all suitable for paddy cultivation due to waterlogged condition by tidal movement. So, it is observed by the results that, the total capacity of the farm for paddy cultivation is 61.4%, but only 50% of the farm found high to moderate suitable. Remaining 11.4 % of the farm needs intensive land management to maintain its capacity and sustainability.

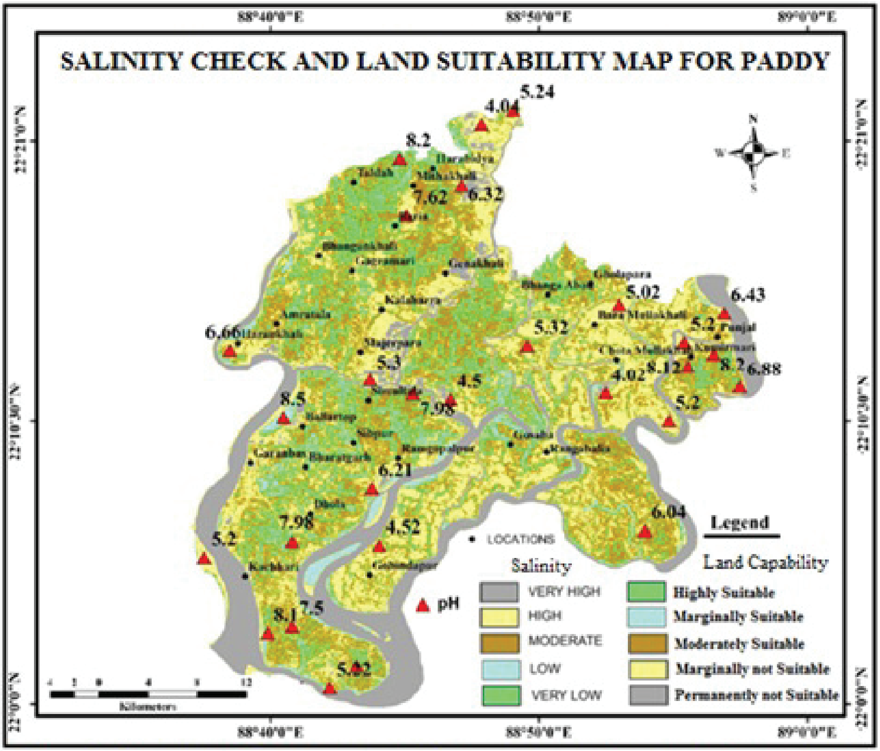

Fig. 15. Validation of salinity from digital indices method with ground sampling and land suitability map for paddy cultivation

5.9. Weighted Overlay Analysis

The salinity zones were identified and mapped by overlaying all the parameters (Landuse/landcover, SAVI and NDSI) which were considered as essential parameters. From perspective of salinity by weighted overlay methods using the spatial analysis tool in ArcGIS. During the weighted overlay analysis ranking and weights were assigned according to the relative influence of the different parameters towards salinity (Table 3).

Table 3. Assigned ranks and weights of different parameters for Salinity Zones

SI NO.	CRITERIA	CLASSES	RANK	WEIGHTS(%)
1	NDSI	VERY HIGH	1	50
		HIGH	2	
		MODERATE	3	
		LOW	4	
		VERY LOW	5	
2	LAND USE/LAND COVER	SALT PAN	1	30
		MARSHY LAND	2	
		MANGROVE FOREST	2	
		WATER BODY	2	
		FALLOW LAND	3	
		AGRICULTURE	4	
		DENSE FOREST	5	
3	SAVI	VERY HIGH	1	20
		HIGH	2	
		MODERATE	3	
		LOW	4	
		VERY LOW	5	

NDSI, SAVI and Landuse/Landcover of 1975, 2000 and 2010 were converted into grid (raster format) and superimposed by weighted overlay method (rank and weightage wise thematic maps). From the analysis of 1975 (Figure 16(a)), salinity zones in-terms of High, Moderate and Low with the areas of 84.56 km^2, 423.69 km^2 and 300.79 km^2 were acquired respectively. The similar procedure was followed to derive salinity zones of the year 2000 (Figure 16(b)) and 2010 (Figure 16(c)). In the year of 2000, the identified areas of High, Moderate and Low salinity were 134 km^2, 163 km^2 and 512 km^2 respectively. Whereas, in 2010 it was 233.46 km^2, 322.20 km^2 and 252.95 km^2 for High, Moderate and Low salinity areas respectively. The fluctuation of area (sq. km) are shown in the Figure 17.

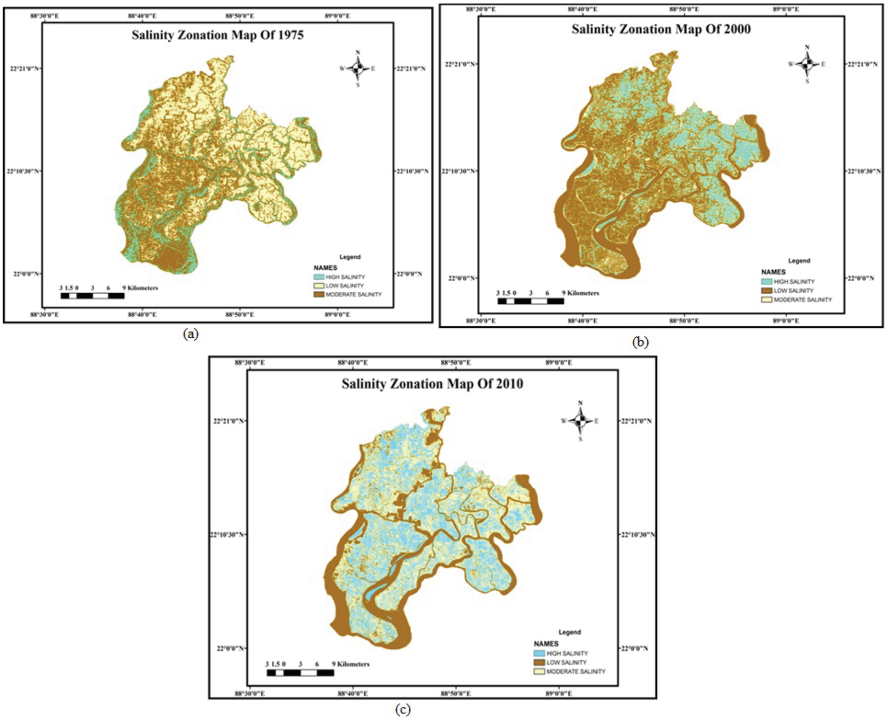

Fig. 16. Salinity zonation of 1975 (a), 2000 (b), 2010 (c)

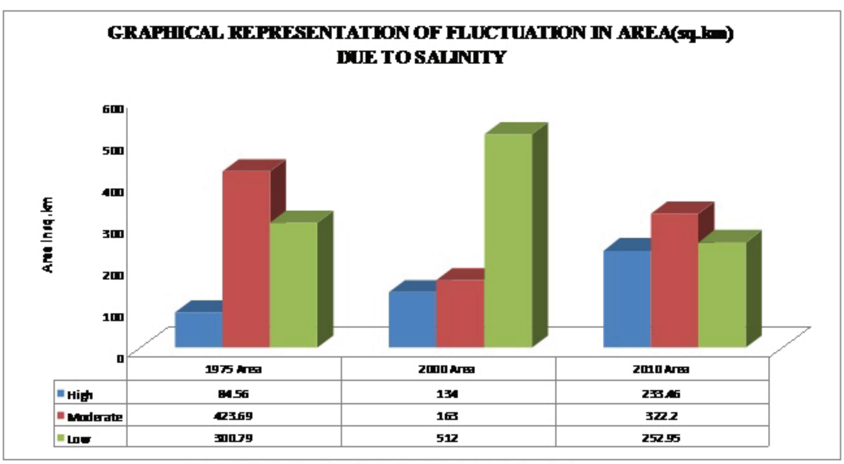

Fig.17. statistics of area covered by different salinity zones

5.10. Salinity Vulnerability Index

Salinity vulnerability index was prepared by overlaying salinity zonation periods from 1975–2010 (Figure 18). The outcome of salinity vulnerability index determines the permanent High, Moderate and Low salinity prone area during all seasonal condition and crop suitability especially for paddy cultivation. The areas of high saline land got increased in 2010 from 2000 as well as 1975. Thus the higher to lower weightage was assigned to 2010 (50%), 2000 (30%), 1975 (20%) according to the influence of most salinity period to less salinity period. The salinity vulnerability index and it's probability of occurrence ranges from 0 to 100. In the figure 18 three permanent salinity zones were classified by software i.e, High, Moderate and Low with the vulnerability index range of 62–91 (High), 36–61 (Moderate) and 7–35 (Low) respectively. It is assumed due to devastating cyclonic effect by Aila in 2009 the immense changes has taken place over the two blocks *Gosaba and Basanti* and the salinity has increased from 1975–2010.

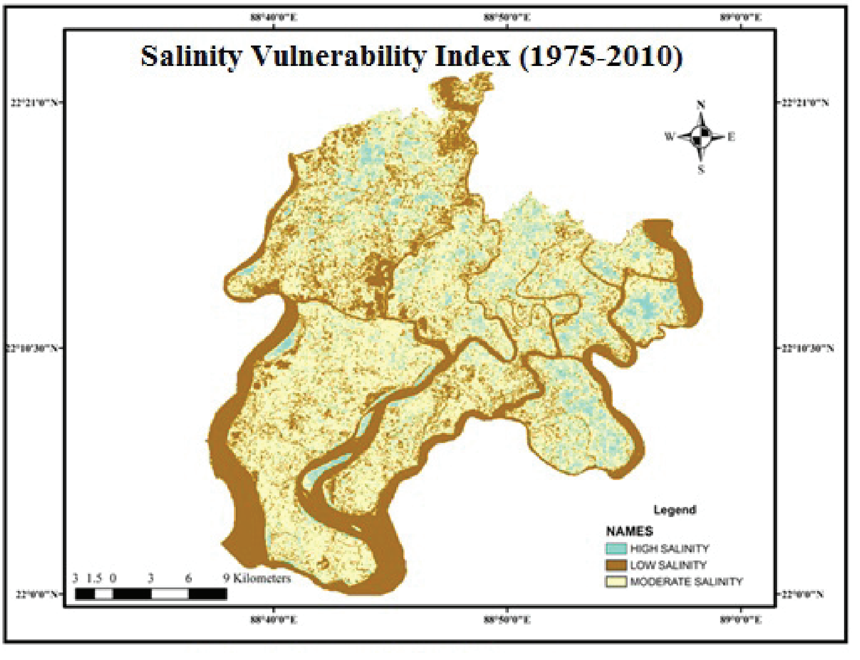

Fig. 18. Salinity vulnerability index map

6. Conclusion

The study area, *Gosaba* and *Basanti* island are prone to cyclonic activities as well as the constant changes due to together contribution of sea water and wind. The soil salinity depends on these dynamic act. Due to over increase of saline condition, the natural vegetation, crop as well as the micro organism might be affected which leads to an adverse effect on environment. Thus, proper management should be taken by initiative of Govt. and local people to protect crop, maintain soil properties and vegetation health. Recently, Mangrove Protection, Building of Embankment, Polderization, building of drainage system along the agricultural field to supply water, avoiding of over fertilization, maintenance of water level in the crop land etc. are being adopted to protect major islands of *Sundarban* region including *Gosaba* and *Basanti* for prosperity and future development.

Integration of remote sensing and GIS can provide valuable information for salinity zone identification and land capability assessment where there is limited and detailed data on soil. The major findings of this project are effectively incorporated and prepared with earth observation and digital indices model to analyze the spatio-temporal scenario over the study area due to dynamic activities by sea and wind over the *Gosaba* and *Basnati* blocks. Most farmers have traditional knowledge that can be expanded with understanding of soil quality and climatic condition to assist to a greater extent on selection of suitable species of vegetables. Methodology in this study can be replicated in other geographical areas of Tamilnadu coastal zone with similar biophysical conditions, to improve the accuracy of land evaluation.The land cover map is used as a layer in the land capability model. The methodology integrated soil data and land cover information in GIS environment that allowed the exploration of different datasets and to present spatially.This study will be helpful to the end users as it benefits the existing land users in determining the most appropriate management practices.

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