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Applying geographic information systems and remote sensing for water quality assessment of mangrove forest

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ABSTRACT

The study of environmental conditions is one of the most important measures in the field of reforestation. The present study was undertaken to assess the environmental status of the mangrove forest of Alibaug, Maharashtra, India with respect to different sixteen physicochemical parameters of water using Geographical information system (GIS) for rehabilitation, conservation and development of the destructed area of the mangrove forest. The Base map of study area was prepared using topographic map and the remote sensing data of Landsat 7 ETM+ for spatial analysis. The distributions of water pollutants were assigned using a GIS approach of Inverse Distance Weighted (IDW). The results showed that the amounts of EC, COD, hardness, O&G, Cl^-, Na^+, Ca^{2+}, Mg^{2+}, NO_3^- and PO_4^{3-} are higher than the normal ranges in mangrove forest due to natural processes and human activity, industrial and domestic wastewater disposal, oil spillage and agricultural runoff which all eventually affect the water quality of mangrove forest of Alibaug. To identify the areas within the normal ranges of 16 studied parameter, suitability map of water was prepared through an integration of 16 suitability maps of the studied parameters. The suitability map of water classified the water to six classes of suitability in order of moderate > moderate to high > low to moderate > high > low suitable. The areas with classes of 1 and 2 were suitable for the protective measures. Classes 3 and 4 were suitable for replantation and restoration of native mangrove species as well as local communities' cooperation in the participatory protection measures. The areas of classes 5 and 0 need to be designed an urgent management and mitigation plan to reduce impact of human activities. The result of the study also proves the use of GIS as a powerful tool in addressing assessment and monitoring programs of the water quality in the mangrove ecosystems.

1. Introduction

Consumption of natural resources resulting rapidly expanding human populations has caused huge impacts to ecosystems across the world. Mangrove forest ecosystem as a base of an elaborate and productive food web in the tropical and subtropical coastal marine environments is one of the most threatened tropical ecosystems [21]. Mangrove zones having an important role as breeding and nursery grounds for many important species are highly productive [1,13,14,24,31]. More than 35% of the world's mangroves are already gone. The figure is as high as 50% in countries such as India, the Philippines, and Vietnam, while in the America they are being cleared at a rate faster than tropical rainforests. Several present studies reveal that following natural hazards and anthropogenic activities are the main cause of degradation of mangrove areas in India [37].

One of the major causes of pollution in the mangrove ecosystem is pollution from industrial and domestic effluents as well as oil spills and solid waste disposal. The nutrients from sewage disposal, including phosphorus and nitrogen under proper and managed situation causing growth of trees and increasing their productivity [34]. The considerable changes were seen when the higher disposal rate was observed than the uptake. Mangrove trees act as sinks for various pollutants. Oil pollution from oil or gas exploration, petroleum production and accidental spills severely damage mangrove ecosystems [18]. In effect, mangrove forests are under stress, which turns into more fragile ecosystems. Mangroves having phytoremediation potential can remove organic and inorganic nutrients and pollutants including heavy metals and agrochemical from the water through adhering contaminants to the particles of sediment and uptake them to the areal parts of the tree via their roots. Mangroves restrict water eutrophication by phosphate and nitrate through denitrification causing lower concentration as well [9]. The type of pollutants ranging from organic and inorganic as well as their chemical properties is the key factors affecting the phytoremediation potential of the mangroves. For last several years interferences in mangroves in

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India, under pressure of urbanization and industrialization along coastal ecosystem, have historically been favored sites for sewage disposal, industrial effluents which have contributed to soil, water and plant contamination. Oil from spills, transport, and refineries along the coastlines further contributes for adverse impacts. Due to these facts, India has taken positive steps to protect and conserve mangroves by way of coastal regulation zone (CRZ) rules. In order to develop sustainable approaches there is a need to understand sources and types of the pollutants responsible for changes in the ecosystem. Therefore, the present study was undertaken to understand the present status of the quality of water. Since extensive studies on physicochemical properties and persistence of pollutants in mangrove forest of Alibaug have not been carried out. The main objective of this study was to know the present status and to identify sources and type of contaminants in the Alibaug mangrove area. To achieve the objective, physicochemical parameters of water which were identified as a water quality indices [29] viz. pH, temperature, EC, TDS, DO, COD, salinity, hardness, SAR, TOG, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and PO_4^{3-} were assessed and the results were interpreted using geographic information system which (GIS) are effective tools for land use/land cover, water quality mapping for monitoring and detection of change in environment [33].

2. Methodology

2.1. Descriptions of the study area

Alibaug is located at Latitudes 18° 56′ N to 18° 29′ N and Longitudes 72° 50′ E to 73° o4′ E in the west coast of India and surrounded on its North East, North and Southern parts by Arabian sea. The temperature is between 38 °C to 8.4 °C with a generally humid atmosphere which average relative humidity is over 80% on the season of monsoon, and 65% to 75% at the remnant of the year, Average rainfall is between 2000 to 2200 mm annually. The dominant species of mangroves are *Avicennia marina*, *Rhizophora mucronota*, *Ceriostagal*, *Acanthus illicifolius*, *Aegiceras cornicuatum*, *Excoecaria aggaacha* and *Brugeria cylindrical* [17].

The distribution of mangroves in Alibaug mangrove forest is mainly influenced by water salinity. *Avicennia marina* or grey mangrove were found along the entire region of Alibaug mangrove forest and in dwarf condition was plenty of the mourn region. As the most salt-tolerant species its upward growth is recorded. As the salinity goes to decrease the height proportionately increase. *Excoecaria agallocha*, known as a back mangrove, is found at higher elevations back away from the forest where salinity is lower. *Acanthus ilicifolius* was found in middle region of the Alibaug mangrove forest as well as tail region. *Rhizophora mucronata* was present in middle region only. *Bruguiera cylindrica* as a small tree which often grows as a bush does not regenerate easily from broken off branches and was present behind other mangroves. *Aegiceras corniculatum* known as black or river mangrove grows as a shrub or small tree and present in middle region [32].

The mangrove forest of Alibaug, the sampling sites and the surrounded land cover are shown in Fig. 1.

2.2. Collection of samples

The water samples were taken using systematic random sampling techniques and collected using sterile transparent plastic jars of five-liter capacity and usually from 10 to 15 cm depth from the water surface from 18 sampling sites and the co-ordinates were noted down with the help of GPS (Global Positioning System). Considering that one of the ultimate landfall areas of the oil spill and pollution disposal would be shore environments, three stations were selected from the Akshi along the coastal area of Arabian Sea and the rest from mangrove forest of Alibaug, Maharashtra, India.

2.3. Sample preparation and analytical methods

To investigate of the status and quality of surface water, sixteen parameters were assessed which were: pH, temperature, EC, TDS, DO, COD, salinity, hardness, SAR, TOG, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and PO_4^{3-}. These parameters were examined agreeing with the [7] and American Public Health Association Standard Methods [2]. All determinations were replicated thrice and the mean value was used to obtain a representation of each station.

2.4. Statistical technique and analysis

The physicochemical parameters of water were compared with normal ranges of parameters in the mangrove ecosystems and seawater standard levels (Table 2) using *t*-test statistical technique at significant level of 0.05 and professional statistical software of Minitab 17.

2.5. Mapping and spatial modeling for distribution of pollutant using GIS techniques

Geographical information system (GIS) is being recognized as a high powered tool in addressing issues and managing geographical information in a holistic manner without losing the spatio-temporal variability which are often critical in assessment and decision making [8,20] Preparing the Thematic maps and modeling of water quality to understanding and proper management of water resources can be done using GIS [35]. The Base map of the study area was prepared using topographic maps and the remote sensing data of Landsat 7 for spatial analysis using GIS. The spatial and attribute database was produced for the each parameter of water samples, then assimilated for the making spatial variation maps of 16 studied parameters. Geo-statistical interpolation technique of Inverse Distance Weighted method (IDW) was applied to assign the manner of the water pollutant distribution and variation according to the physicochemical parameters of water [3]. Preparation of variation and Suitability maps was done using ArcGIS 9.3 software.

3. Results and discussions

The statistical summary of physicochemical parameter of water during January to March 2010 and a Comparison of the studied parameters in water samples of the study area to normal ranges in mangrove forest and seawater are shown in Table 1 and Table 2 respectively. The Table 2 shows the results of statistical analysis and indicates differences at the significant level between the mean value of underlined studied parameters and their normal ranges in the mangrove ecosystem. Study on physicochemical properties of water in mangrove forest has been reported by various research work [4,10,16,30].

3.1. Temperature

The temperature of surface waters is influenced by latitude, altitude, season, time of day, air circulation, flow and depth of the water body. In turn, temperature affects physical, chemical and biological processes in water bodies. If temperatures exceed 35 °C, root structures, seedling establishment and photosynthesis of the mangrove trees will be negatively affected [15]. The water temperature ranged between 23.74 and 36.36 °C. The mean value of 29.73 revealed a mesophilic to thermophilic temperatures. The standard deviation of 3.94 shows high variability in the temperature during the time of sampling. The variation map of temperature (Fig. 2.a) shows that the temperature in the study area, mostly ranged between 18 - 31 °C at the time of sampling. Suitability map of temperature is shown in Fig. 3.a. The suitability map shows that the majority of mangrove forest lies between the normal range. Similar results were reported by [25,26,28].

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