# GIS: Vital Tool for Fisheries Resource Management

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## Abstract:

Fisheries continue to be a thrust area of India's development programs due to their very important contributions to employment generation, food security and foreign exchange earnings. There is a need for assessment of fisheries ecosystems, environmental problems due to prevalence of various activities and management needed. With a view to have a systematic approach, studies, such as coastline changes and their effect on coastal life, mangrove mapping and change detection, mapping of salt-affected and waterlogged areas for aquaculture, site selection for brackish water aquacuture, have been carried out using ArcGIS. Mangrove mapping of Mumbai showed 39.42 percent decrease in area of mangroves during 1990-2001. Brackish water aquauclture site selection showed 9.873 percent is suitable from the total study area. A study of shoreline changes of Mumbai coast gives around 26 km2 accretion and 1.1 km2 erosion from 1966 to 2002. GIS proved to be a vital tool for sustainable development and utilization of fisheries resources.

## Introduction

Coastal zone includes both natural features like beaches, wetlands, estuaries, lagoons, coral reefs, rocky coasts, dunes etc and manmade features such as ports, commercial fisheries and aquaculture operations, industries, tourism and recreation developments, archeological sites and some of the largest and most densely populated urban areas in the world. It is also used for off shore oil and gas, marine transport as well as dumping ground for disposal of wastes. An important function the coastal zone performs at no cost includes shoreline stabilization, fish nurture, recreation besides providing habitat for nearly all shellfish and finfish used for human consumption and in commercial fisheries. Apart from these, coastal areas are also rich sources of food, energy and minerals and therefore a primary source of livelihood for a large part of the world's population. They also produce biological resources and sustain functions that are crucially important to the local, regional and global environment.

The coastal zone is therefore both ecologically and economically significant due to which coastal areas around the world are increasingly subject to high population pressure and multiple economic activities across several factors i.e., economic development, rapid population growth and migration form inland to coastal areas, exerts increasing pressure on coastal resources (World bank, 1994).

Coastal zone is a very complex, dynamic and delicate environment, because this area is a transition, mixture between land and marine process (Gunawan, 1998). Therefore, in this area relatively quick changes are expected to occur. For example, in the coastline, abrasion occurs in some place and sedimentation occurs in another part or even occurs in the same area but in different time periodically. Human activity will increase the complexity and speed up the process that caused the changes. All these frequently result in cumulative and complex impacts on the environment, depletion of resources and intensified conflict between competing user groups such as those relying on the coastal resources for livelihood and source of income and those interested in recreational uses of coastal area.

It has been estimated that the coastal domain covers 18% at global surface, 25% of global primary productivity and about 60% of the human population lives in a coastal band of 50 km wide and half of them in developing countries and the United Nation’s estimate for the year 2000 was 75%. In addition to that, an estimated 40% of human population resides within two kilometers of the coast. The coastal ocean forms 8% of the ocean surface and the ocean holds over 90% of land-based pollution (Tripathi, 2002).

Shoreline is one of the most rapidly changing landforms of the earth and geomorphic processes such as erosion, deposition and sedimentation, periodic storms, flooding and sea level changes continuously modify the shoreline. Therefore, the accurate demarcation of shoreline is very important for the planning conservation measures.

The study of coastal processes includes two major elements i.e. study of shoreline and coastal landforms. Aerial photography is the original form of remote sensing and remained a widely used method. Interpretations of aerial photographs have led to the discovery of many oil and mineral deposits. These successes, using only the visible region of the electromagnetic spectrum, suggested that additional discoveries could be made by using other wavelength regions. In the 1960’s technology was developed to acquire images in the infrared (IR) and microwave regions, which greatly expanded the scope and applications of remote sensing.

Remote sensing data can be used to evaluate the coastal processes like littoral drift, erosion/ accretion and shoreline changes and to study water geomorphology landforms, sediment concentration, water quality etc. Therefore, the application of remote sensing technique with the help of satellite data enable the study of the past and at the same time allows us to witness the changes due to its repetitive coverage and revisit capability.

The capability of satellite remote sensing to provide synoptic, repetitive and multispectral data has proved to be very useful in the monitoring of coastal features such as tidal wetlands, coastal landforms, potential aquaculture sites, mangroves, estuary dynamics, off shore aspects like suspended sediment dynamics, coastal currents, internal waves etc including shoreline changes. Remote sensing is also used for location of potential fishing zones based on sea surface temperature (SST) and chlorophyll.

Geographical Information System (GIS) is a computer based information system used to digitally represent and analyse the geographic features present on the earth's surface and the events (non-spatial attributes linked to the geography under study) that are taking place on it.

GIS is both a database system with specific capabilities for spatially referenced data as well as a set of operations for working with the data either separately or in combination.

All these make a GIS an important analysis tool. The major advantage of a GIS is that it allows identifying the spatial relationships between features. To find out temporal changes, GIS can give the exact information or differences within an area over a time. It can best be useful to monitoring changes in landuse in coastal zone and it is possible to quantify the area of changes (erosion/accretion) along the coastal zone. Applications of GIS in fisheries and aquatic science research and management include: mapping and modeling fish distributions and habitats, mapping marine protection areas and coastal zones, sighting aquaculture facilities, generating global warming scenarios, and assessing watershed land use activities on lake and stream fish habitat. GIS facilitates the evaluation of spatially-oriented fisheries problems through spatial modeling and visualization.

Therefore in this context the prime objectives of GIS in fisheries may be to:

- detect the change in shoreline of coast using remote sensing data
- find out the areas undergoing erosion or accretion process in the coastline using GIS
- to find suitable area for aquaculture
- to identify the potential area for the commencement of sustainable shrimp farming with the help of remote sensing and GIS
- mapping of mangroves
- mapping of fisheries data

**Central Institute of Fisheries Education** (CIFE) is one of the four Deemed Universities under the Indian Council of Agricultural Research (ICAR), New Delhi, INDIA. It imparts postgraduate education in fisheries leading to Masters and Doctoral Degrees, besides conducting need-based short-term training programme. One of the major disciplines and fields of specialization is Biostatistics and Informatics which cover Fisheries Statistics, RS & GIS applications, Fisheries Informatics. Our team in Fisheries Informatics & Technology Evaluation and Transfer Division has done study in some of this area.

## Methodology

Satellite data processing and information extraction

Geometric correction is applied to raw data to correct errors of the perspective due to the earth's curvature and sensor motion. Polynomial rectification is the process of transforming the data from one grid system using an nth order polynomial. Since the pixel of new grid may not align with the pixels of the original grid, the pixel must be resampled which is the process of extrapolating data values for the pixels on the new grid from the values of the source pixels. (ERDAS,1999). Also district and taluka level maps with village information were created using ARSGIS.

## Overlay

Classified images were then imported to ArcGIS where different features were digitized. Then the polygon were cleaned and built. In order to find out areas of increment polygon themes of following year were overlaid using ArcGIS.

**Case Study 1. Mangrove mapping of Mumbai**

Location of study area: Greater Mumbai

Data used : IRS-1D data of 8th March 2001, IRS-1C data of 24th Dec 1996, SPOT data f 23rd Nov. 1990

Methodology : simple principles of photo interpretation to detect and demarcate mangrove growth in the study areas. Map layers generated in 1996 and 2001 were geo-registered using GCP in ArcGIS.

Result & Discussion : The study revealed that mangrove coverage during 2001 in Mumbai was 56.4 km2 , forming nearly 12.05% of the total area of 468 km2.Estimates of area of mangroves in Mumbai based on previous studies using extensive field survey techniques. The change in area of mangroves pertaining to the Mumbai suburban region for a period of 11 yrs from1990-2001 reveals that a total area of 36.54 km2 was lost. This accounted for 39.32% decrease in area under the mangroves. There was loss of 44.28 km2 in Sparse mangroves and interestingly a gain of 7.74 km2 in the dense mangrove area during 1990-2001. It is observed that in 11 year period mangroves have been receding at the rate of 3.32 km2 /yr.

**Table1 : Area under mangroves in Mumbai**

| Year | Mangrove Classes | | Total Area ($Km^2$) |
|---|---|---|---|
| | Sparse Mangroves ($Km^2$) | Dense Mangroves ($Km^2$) | |
| 1990 | 75.08 (80.78%) | 17.86 (19.22%) | 92.94 (100%) |
| 1996 | 43.44 (64.92%) | 23.47(35.08%) | 66.91(100%) |
| 2001 | 30.80(54.61%) | 25.60(45.39%) | 56.40(100%) |

**Case Study 2 .Brackish water aquaculture site selection**

Location map : coastal area of Palghar Taluka, district Maharashtra, India.

Geographical importance: Intertidal areas were evaluated for the development of brackish water aquaculture and the data on 37% under six major categories namely engineering parameters, water quality parameters, soil quality parameters , infrastructure facility, meteorological parameters and social restriction were collected.

Data used : IRS 1D Liss III FCC print

Result & Discussion :

The reclassified image was used to identify sampling points for accessing aquaculture suitability. The total cumulative weighting of all the thematic layers was calculated on a 0-300 scales. After overlaying all the seven layers a composite map was obtained with total cumulative weighting of mudflats varied from 4 to 12. For lands away from the 3 km buffer zone , a zero total cumulative weighting was assigned . using these ranges aquaculture suitability and priority maps were obtained by regrouping the integrated map. Of the total study area of 20431.034 ha, 0.377% was found highly suitable, 9.873% suitable, 1.772% moderately suitable, 85.027% unsuitable while 2.951% is already under aquaculture.

Analysis of data on engineering parameters , soil quality , water quality, infrastructure facilities , meteorological data and social restriction with the help of GIS technique resulted in a map showing suitable areas for the improved method of shrimp farming. In the study area, lands adjacent to mudflats are used for agriculture by making partition to prevent the entry of tidal water.

As the accuracy of these kind of studies is directly dependent on the quality of input data, updated and accurate thematic information are mostly desired. In the study , the parameters mainly considered for *P.Monodon* species but for other species the same parameters can be used with some modifications. Classification of limitation category of water qualiy parameters needs to be changed for the other species as per their body physiology.

The study demonstrated the potential use of remote sensing, GIS and GPS techniques for aquaculture site selection and planning for responsible coastal aquaculture. In order to plan aquaculture at national level, multi-objective land allocation method needs to be followed to avoid land conflicts in the subsequent years among different stakeholders.

**Case Study 3. Coastline changes of Mumbai coast**

Location map : Mumbai

Data used : Indian remote sensing satellite images (IRS ID LISS III) of 2002 of Mumbai shoreline along with Survey of India (SOI) toposheet (47A/16) (1966-67)

Result & Discussion :

From the study of satellite image and field visits various geomorphic units can be identified; beaches, mudflats, mangroves, saltpans etc. Among these the most sensitive geomorphic units along the coast are observed to be the coastal mudflats and mangroves that occur between high tide line and low tide line. These mudflats and mangroves are affected mostly by anthropogenic conversion and pollution. Changes in shoreline of Mumbai coast during 1966 to 2002 is depicted in Plate 8.

From the comparison of shoreline of two different years i.e. 1966 and 2002 a total accretion of 26 $km^2$ is detected along the western side of Mumbai coastline particularly at Mahim-Bandra creek, southern Bandra, near Khar-Danda, near Juhu, south of Versova. Intense accretion was noticed along Malad creek particularly between Darvili and Charkop and north side of Manori creek i.e. at Gorai. Accretion has also been noticed at western part of Yoginagar. Raster layouts generated after polygon overlay method showing accretional and erosional sites are depicted in Plates 9,10 and 11.

The general conclusion of the present work, however, is that the shoreline along the Mumbai coast has changed much during last 36 years. The main reason is said to be anthropogenic interference and human settlement all along the coast. The shift in high water line and accretion has taken place mainly due to reclamation activities along the beaches. At many places intertidal area has also decreased considerably. Accretion and erosion at different places along Mumbai coast are shown in Plates 12 to 19.

TABLE : TOTAL AREA OF EROSION AND ACCRETION

| | **Change analysis** | **Quantity ($Km^2$)** |
|---|---|---|
| 1. | Area of Accretion | 26 |
| 2. | Area of Erosion | 1.1 |

**Case Study 4**. Coastline changes in Alibag coast

Similar kind of study along the Maharashtra coastline was carried out. Area was Alibag coast in Raigad district using RS & GIS has been carried out.

Location map : Alibag in Raigad district of Maharashtra

Data used : For this study we used 1971 SOI toposheet, IRS-1D, LISS III satellite image of 3rd March 2003 from NRSA.

Result & Discussion :

From the study of the satellite image & field visits geomorphic units were identified , beaches , saltpans, sand dunes, mangroves etc. From the comparison of shoreline bet’ 1971 & 2003  a total accretion of 6.5 $km^2$ was detected along the Alibag coastline. This was found particularly at Varsoli, Thal, Revdanda & Korlai. Compare to accretion , erosion found less. Erosion was observed in places like Kihim, Alibag beach south of Nagoan & east of  Korlai. Total erosion in these areas were found to be 3.81 $km^2$. Among the total  71.67% of the sample respondents faced with salinisation of water in wells. In koliwada 96.67% of respondents were facing salinisation

In water whereas in Varsoli 46.67% were having the problem of salinisation in water.  Socio-economic status: the data collected from survey of two villages, Varsoli, Koliwada were tabulated and analysed. Impact of shoreline changes on coastal population was studied. A total of 96.67% were aware of shoreline changes. About 71.67% of the sample respondents faced with salination of water in wells. In Koliwada 96.67% were facing  salinisation inwater & in Varsoli 46.67% were having same problem.

The survey clearly showed that there was decrease in landings in both villages Varsoli and Koliwada. Almost 50% of the total respondents had reported a 50-75% decrease in the landings and 40% of the total had reported more than 75% decrease in the landings. The decrease in landings was found to be more in Koliwada than Varsoli.

Accretion per year was found to be 0.2 $km^2$ along Alibag coast which is less than that reported in Mumbai where it is 0.72 $km^2$/ yr. Severe accretion was notices along Revdanda & Korlai which may be due to land reclamation because of the presence of an industrial unit (Vikram Ispath Ltd.) Erosion was found to be 3.81$km^2$ during the period of 1971-2003, in places like Kihim, Alibag beach, south of Nagoan & east of Korlai.

The main occupation of fishermen families living along the coast of Alibag were fishing. They were living in close proximity with the sea so that their life style, culture , community and social life were centered around the sea. The impact survey results from the two coastal villages of Alibag showed they were aware of shoreline changes.About of half of the respondents have reported that the landings decreased by 50-75% . the decrease in landings may be due to pollution, physical destruction of habitats due to shoreline changes. The fish landings of State Department of Fisheries also confirmed these results. Thus the shoreline changes resulted in change of residence, loss of property, salinisation in land and water, as well as decrease in landings.

**Discussion**

Studying all these areas we feel GIS is revolutionizing the fishing industry, allowing users to meet their objectives more efficiently, and providing them with problem solving capabilities that were never before possible Geographical Information Systems (GIS), combined with other ArcGIS analytical tools and models, can allow for improved spatial monitoring, analyses, and eventually better and more effective management practices. Geographic information systems and related fields, particularly applications of fisheries monitoring and management, fisheries GIS and other integrated information systems, decision support systems for fisheries, can be developed.

According to FAO some of the areas where we can implement GIS are :

**FISHERY POLICY AND PLANNING**

- Application of GIS for inter-sectoral planning and management;
- Privatization of state and parastatal fisheries enterprises;
- Effects of macro-economic policies on fisheries and coastal resource use.

**MARINE RESOURCE MANAGEMENT**

- Risk assessment in Fisheries Management ( with particular emphasis of setting of total Allowable Catches)
- Risk management in the Public Administration of Fisheries Analysis of *Decadal* Phenomena affecting the abundance of Fisheries
- Methodology and applications of Geographical Information Systems as aides to Fisheries Management
- Methodology and application of Resource Mapping as aides to Fisheries Management
- Applied Resource Management Modelling

**INLAND FISHERIES MANAGEMENT**

- Enhancements, particularly stocking and ranching, and in particular their economic aspects.
- Geographical Information Systems (GIS) for management decision-making in fisheries.
- GIS for environmental decision-making affecting fisheries such as integrated lake and river basin management.
- GIS for allocation of uses between fisheries and aquaculture and between fisheries and other competing uses.
- Integration of databases into multi-media packages assessing trends in catch, production, occurrence. Conventional management of inland fisheries.

**AQUACULTURE DEVELOPMENT METHODS**

- Participatory rural appraisal methodologies for rural small-scale aquaculture projects.
- Development of a methodology for the formulation of intermediate (semi-commercial) aquaculture projects.

**AQUACULTURE DEVELOPMENT INFORMATION / AQUACULTURE IN RURAL DEVELOPMENT AND EXTENSION SYSTEMS**

- Aquaculture nutrition and feeding information, databases & resource atlases.
- Development and assessment of aquaculture data bases related to the SIPAM/SIPAL systems.
- Compilation and evaluation of new technical developments in aquaculture research and production.

**AQUACULTURE PLANNING**

- Development of sustainability indicators
- Preparation of technical guidelines for specific elements of aquaculture (follow up on the Code of Conduct for Responsible Fisheries)
- Analysis of trends and driving forces in aquaculture development.
- Refinement and use of GIS and remote sensing as development and management tools.
- Integration of aquaculture into farming systems and rural development.
- Resource utilization in aquaculture systems.
- Aquaculture-environment interactions in the tropics and sub-tropics.
- Creation of expert systems on species introductions.
- Genetics and Biodiversity affecting both Inland Fisheries and Aquaculture.
- Review of literature on species introduction and augmentation of findings into databases.
- Creation of user friendly software for genetic stock identification.

**FISH PRODUCTION**

- Impact of fishing on the environment

**FISH UTILIZATION AND MARKETING**

- Fish processing technology and marketing
- Fish inspection and quality assurance, seafood safety (HACCP) and trade

## Conclusion

Since using GIS techniques along with ArcGIS software one can create maps that are the same or superior to those which are produced by manual methods. This fact is evident by the large number of governmental and commercial cartographic organizations that are moving over to ArcGIS for map production. Reports and statistics produced from ArcGIS can be very well use for monitoring and management.

When joined with database management system technology and miscellaneous data gathering procedures, ArcGIS makes it a great deal easier to produce and preserve extensive information about natural resources. Thus, many issues, which previously were not approached systematically since the data were too huge and costly to accumulate or the analysis took too much time, can now be addressed explicitly. Using ArcGIS software means it is easier to deal with problems through query and reporting efforts not very different from other kinds of routine management operations.

What is still yet to be found, and what is potentially most significant about GIS technology, is whether GIS technology can contribute to the solution of the problems which have been sketched out above. To put it briefly, GIS technology along with ArcGIS can make a difference in fisheries resource management.

**Acknowledgements**

The Authors are thankful to Dr. Dilip Kuma, Director and Dr. S.C. Mukherjee, Joint Director, Central Institute of Fisheries Education (CIFE), Mumbai for providing necessary facilities for the study.

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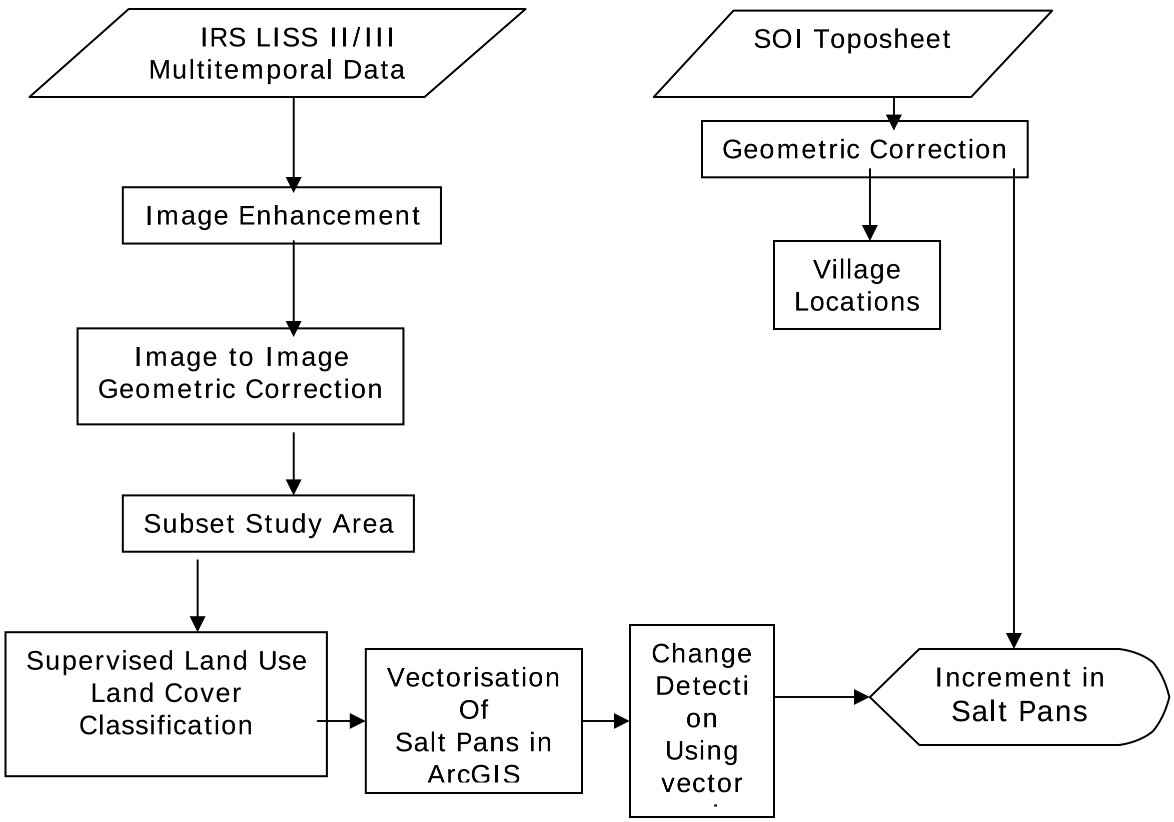


Figure.1 Flow diagram of methodology

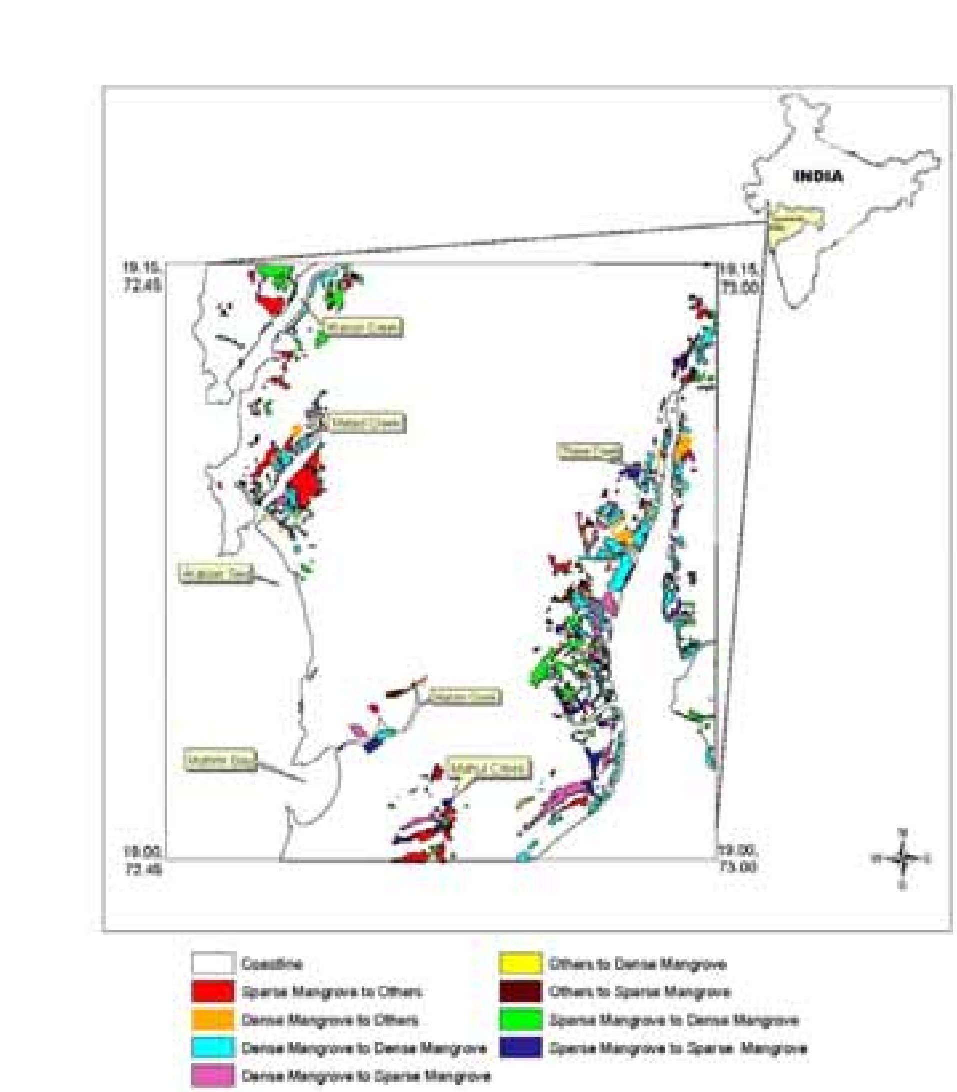


Fig 2: Mangrove mapping and change detection around Mumbai

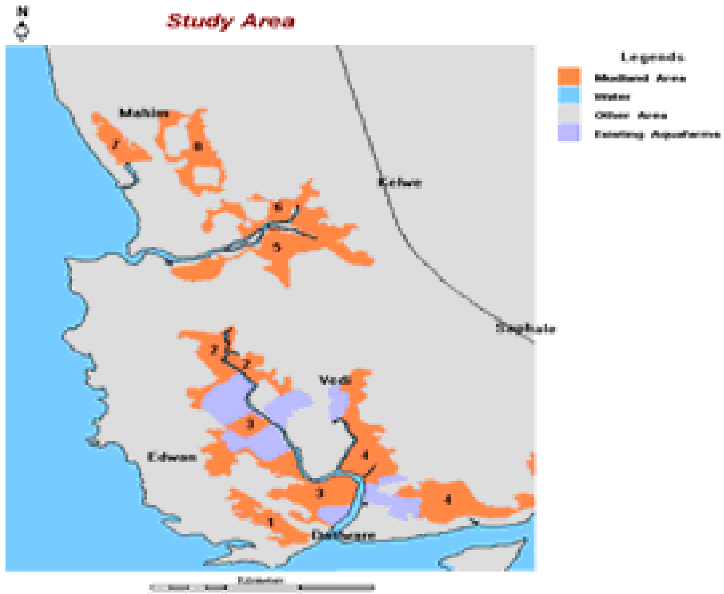


Fig. 3 : Study Area for Aquaculture Site Identification

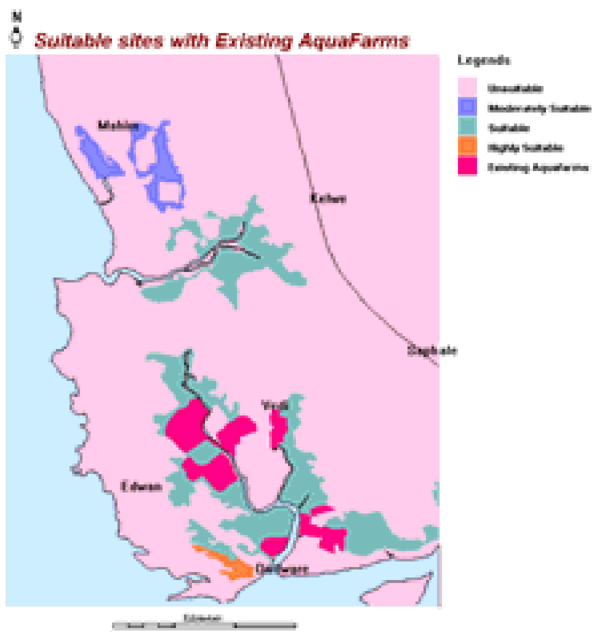


Fig 4: Suitable Sites with Existing Aquafarms

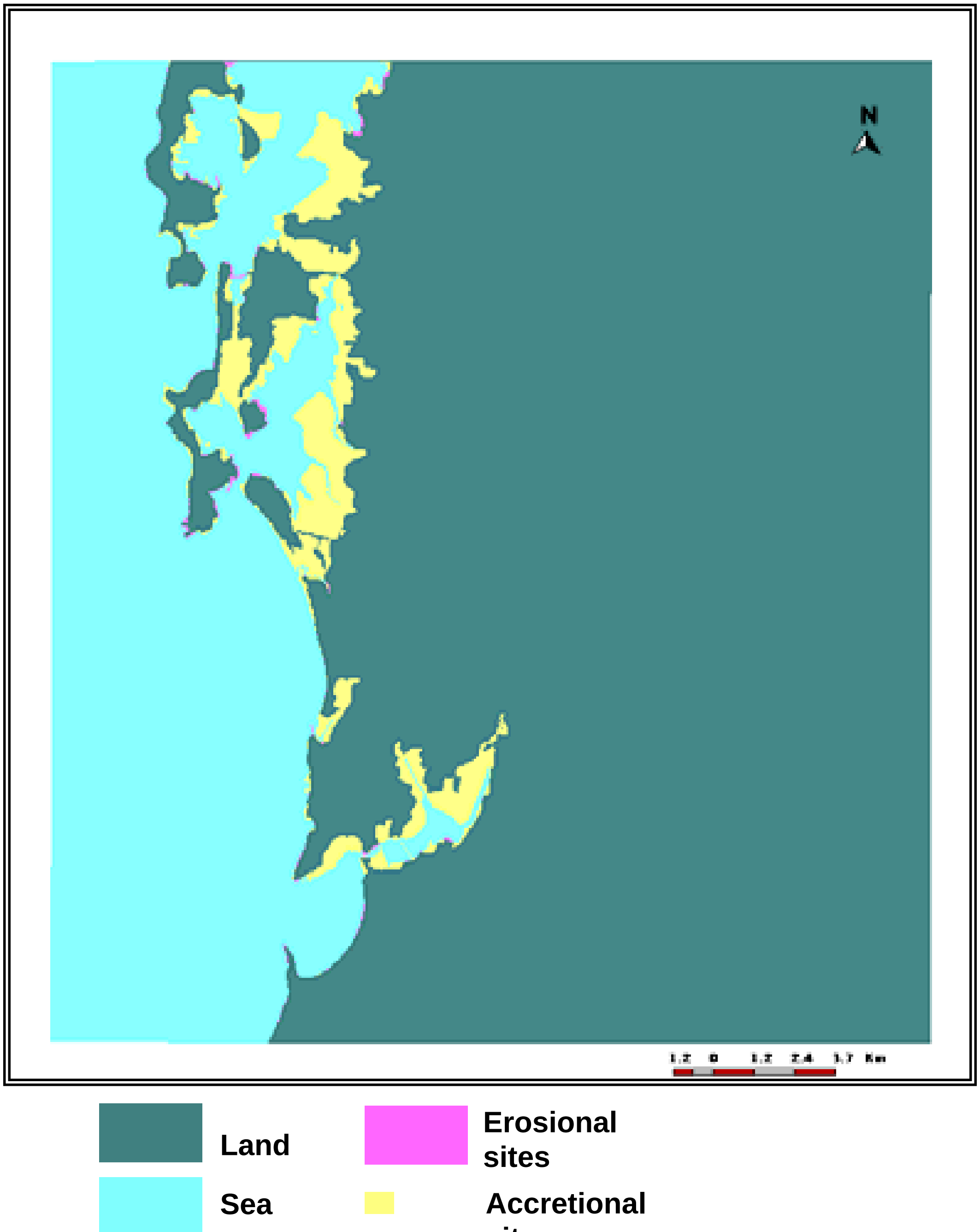


**Fig. 5: Raster layout showing change in HWL along Mumbai coast (1966-2002)**

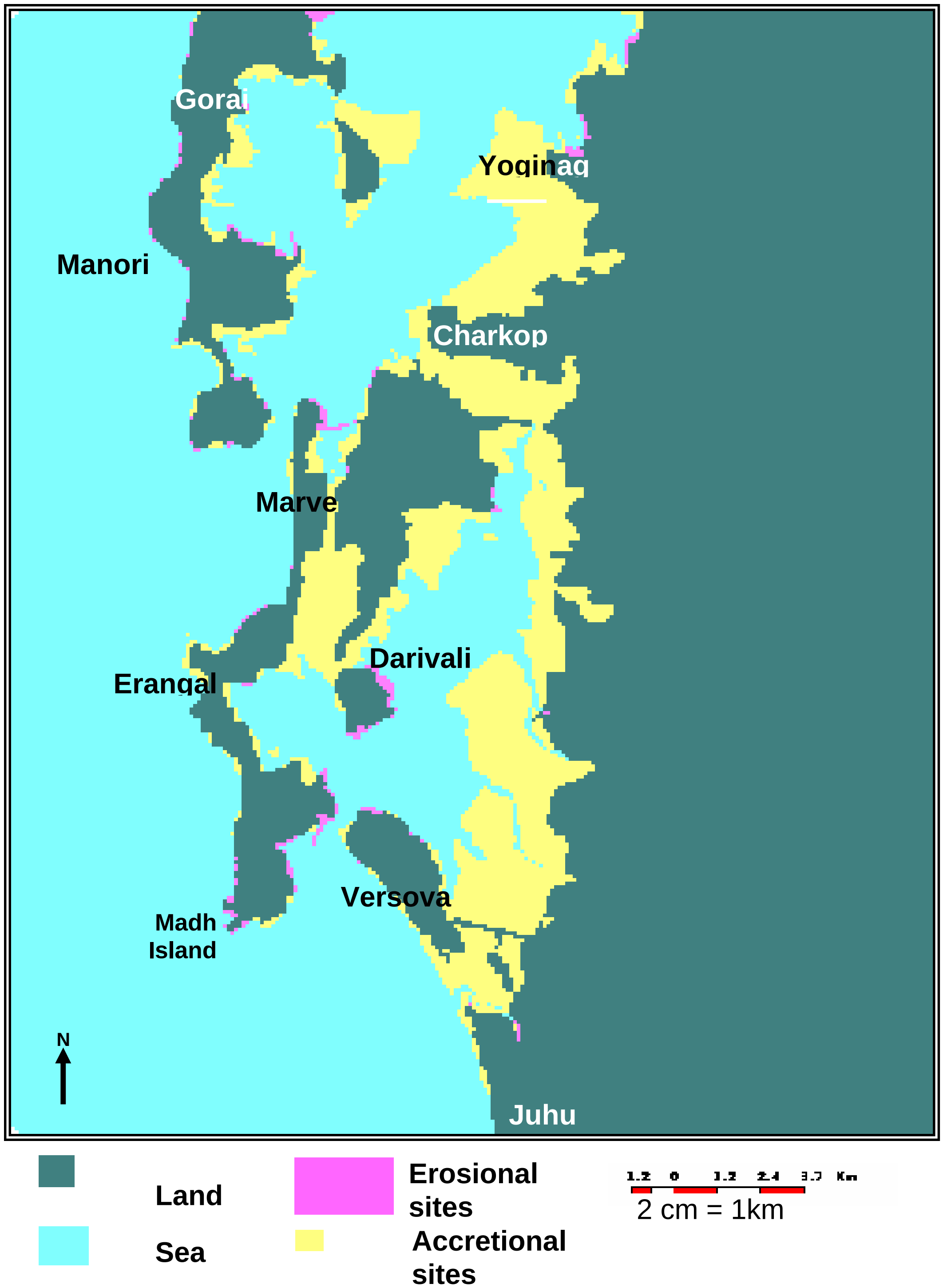


**Fig. 6 : Close-up view of raster layout showing change in HWL between Juhu and Gorai (1966-2002)**

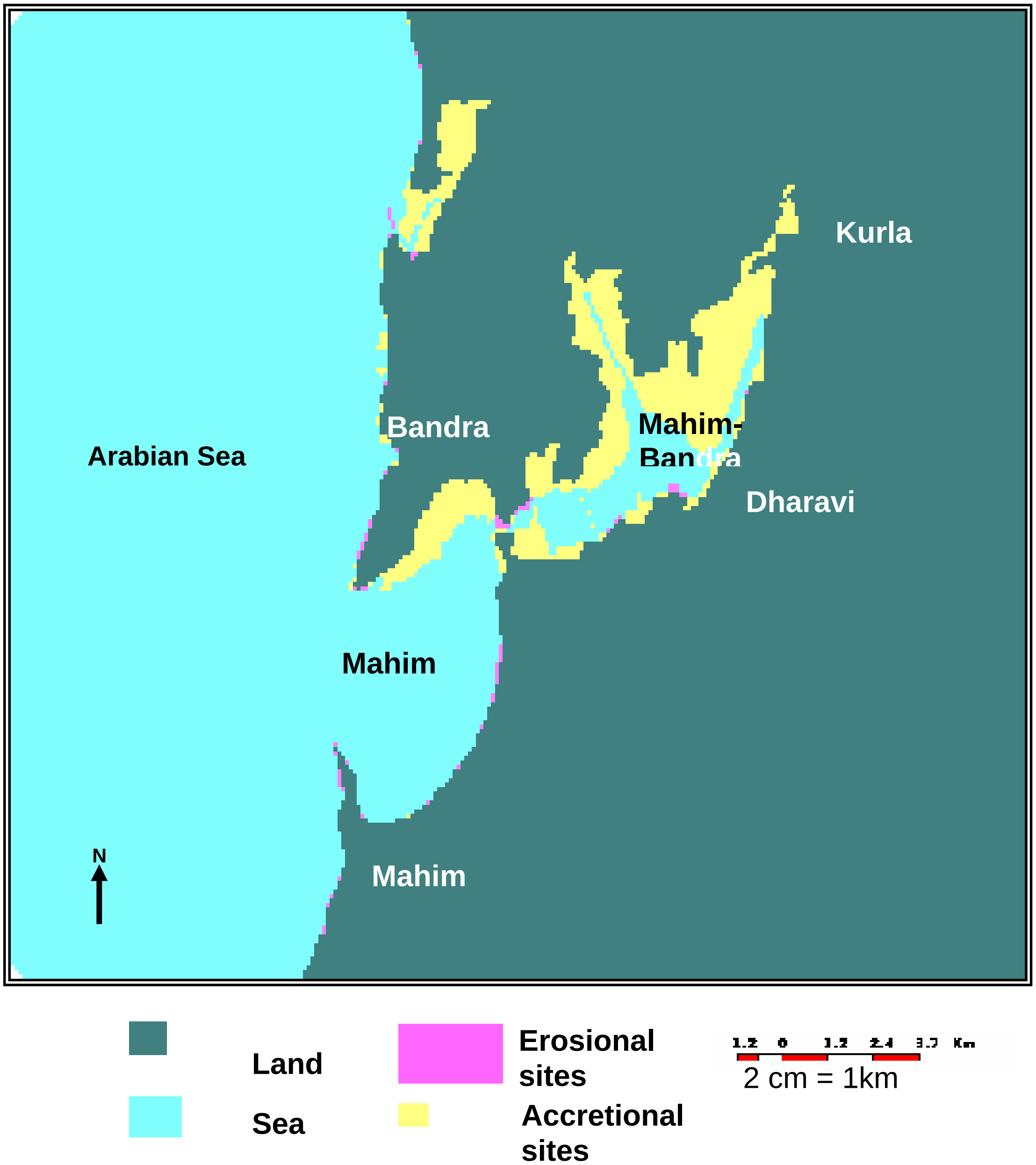


**Fig. 7 : Close-up view of Raster layout showing change in HWL Mahim-Bandra creek region(1966-2002)**

**Plate 1: Photograph showing Bandra reclamation**

**Plate 2: Photograph showing encroachment of slums at Mahim-Bandra creek**