"Indexing of geospatial data by using GIS techniques for sustainable use and management of coastal natural resources in India"

Shubhankar Biswas*, Dineshbabu A.P, Sujitha Thomas, T. Shailaja Salian
ICAR-Central Marine Fisheries Research Institute, Mangalore Research Centre,
P.B. No 244, Hoige Bazar, Mangalore, Karnataka, India -575001

Abstract: Increasing anthropogenic activities in sensitive coastal environments has drawn a global attention in present era and protecting coastal zones from over exploitation has become a subject to remarkable stress in coastal management of India. Several studies has already described that Remote Sensing (RS) and Geographic Information System (GIS) are combined and advanced decision support system for storing, structuring and analyzing any information in a scientific way. The present paper provides an overview of GIS application for conserving natural resources and making a smart coastal area in India. It is also described that how a decision support system can be developed for monitoring & outlaying any coastal area to plan out the various activities along the coastal zones. The GIS technology was used here to provide the information for micro and macro level spatial planning of natural resources of coastal areas in India on a sustainable basis. For mapping, monitoring and indexing the study area ArcMap and ArcScene, two basic and powerful platforms of ArcGIS software were used. With the help of tools in ArcTool box like 3D analyst, Spatial analyst, Multidimension tools etc. and respective methods like Raster interpolation, Raster surface, Extraction were applied for geographical referencing, projecting the area and generating contour lines. This technique helped in identifying the suitable area for ecological coastal activities like mangroves conservation, bivalve fishery, prawn farms, crab culture potential area, small scale

About the Authors:

Dr. A.P.Dineshbabu, Principal Scientist, Crustacean Fisheries Division, ICAR CMFRI has 24 years of experience in marine fisheries Management. He is the pioneer in GIS resource mapping of marine species in India. Have 108 papers to his credits out of which 10 is GIS papers. He is Principal Investigator for all India project on GIS Marine Resource mapping of ICAR-CMFRI.
dineshbabuap@yahoo.co.in

Dr. Sujitha Thomas, Principal Scientist, Demersal Fisheries Division, ICAR, CMFRI, Mangalore has 21years of experience in marine resource management and mariculture. She is one of the pioneering in GIS resource mapping in India and has 76 papers to her credits out of that 10 GIS papers.
sujithacmfri@yahoo.co.in

T. Shailaja Salian, Senior Research Fellow, CMFRI, Mangalore has 7 years of experience in GIS marine resource mapping in ICAR- CMFRI. She is associated with marine resource mapping in India since its inception. She is well versed with ArcGIS tools and its applications in Marine resource mapping.
shailajasalian@yahoo.co.in

cage culture site, and areas of high organic load. As a result of the process an exclusive 3D demographic structure of the study area was modeled, which contains valuable information of the area, future possibilities and scopes for using natural resources from coastal area. This spatial information helped in depicting the various uses of coastal ecosystem and human interfaces and also to project the possible interventions from that area in future. This pictorial 3D representation gave more visual clarity to understand, analyze and plan the area in a better way. Thus the user friendly ArcGIS software has extended its application in the marine resource management and acts as a support system to make decisions and policies in coastal natural resource management.

Keywords: Natural Resources Management, ArcGIS, 3D Analyst Tool, Spatial Analyst Tool, Spatial Planning, Decision support system.

Shubhankar Biswas, Junior Research Fellow, CMFRI, Mangalore, is associated with GIS field since 2014. He is well versed with ArcGIS, R statistical software and modeling using marine fisheries science.
subhankar.biswas025@gmail.com

E mail ID: subhankar.biswas025@gmail.com

Contact: +918971765027

Introduction

Use of GIS is gradually increasing day by day, as terrestrial as well as marine area. Environmental planners, researchers, resource managers and the scientific communities became aware of the techniques of this GIS decision support system. This decision support system has the capability to integrate with different forms of geographical data for developing spatial data infrastructure, which can be used for analysis in many areas. Similarly, preparing a spatial data infrastructure in coastal area with remote sensing and geographical information system can be effectively used to conserve and utilize natural resources of that area though it is one of the key challenge processes of present research. The present paper an insight into the GIS technology which could be used to developed spatial database for micro and macro level spatial planning of natural resources of coastal areas in India on a sustainable basis. According to Centre for Coastal Zone Management and Coastal Shelter Belt of India, the total length of coastal boundary of India is 7516.6 km with large numerous coastal wetlands, lagoons, mangrove areas etc. which is natural protected zone of living and non-living resources. These wetlands, mangroves, sea grasses are very much productive and ecologically important resources for food, energy, tourism and economic development of any coastal area (Shailesh Nayak et al 1996). But such valuable coastal zones are also affected by various natural and human activities. Indian coastal areas are the witness of increasing anthropogenic activities like various modes of marine transport, marine fishing process, rapidly urban, industrial and recreational growth, rising disposing amount of terrestrial wastes into sea etc. all of which is giving high stress to coastal environment and its resources management because natural resources are considered as capital assets of any coastal zone and which has to be conserved for future.

In view of the dynamic nature of the coastal zones, an accurate scientific demographic structure on exclusive coastal zones is very much essential. To develop the structure GIS can be used for integrating satellite based information and field survey data to identify aquaculture sites, coastal regulation and environmentally

sensitive zones (Shailesh Nayak et al 1996). Satellite Remote Sensing Systems and Geographic Information Systems are the primary tools for addressing coastal resource management issues, and have become most evident in almost every field of science and management (Haddad and Michener, 1996). These tools have opened the door to new studies, and allowed characterizing ecosystems over a range of very local scale (Wulder et al., 2004). GIS allows any spatial qualitative and quantitative data types to identify associations between both components, and therefore, build a "living database" with data analysis and mapping capabilities (Booth, 1998).

This advanced scientific tool is also extremely valuable in developing databases and analyzing that database in an integrated manner for taking decisions and actions to build a smart coastal zone. For ecologically important and designated sensitive coastal areas, detailed mapping and modeling through GIS techniques can provide resolution in identifying the real extent of any anthropogenic activities and linking to possible ecological consequences and which enhances our ability to manage the region of interest in priority for resources utilization and conservation (Leah I. Bendell & Peter C. Y. Wan, 2010). RS and GIS-based approach with regular field study would illustrate the possibilities and constraints of GIS technology in linking two fields like marine and terrestrial, as aimed in this paper. For building the smart and advanced interrelationship link between land and ocean, ArcGIS is an adequate tool for successful planning and management of the given coastal area.

Study Area

The study area is located at Byndoor, a coastal area of Kundapura taluk in Udupi, a coastal district of Karnataka in south India. It lies between $13^0 52^/ 20^{//}$N to $13^0 51^/ 00^{//}$N latitude and $74^0 36^/ 10^{//}$E to $74^0 37^/ 00^{//}$E longitude (Fig 1). The study area covers the Sumana river estuary, which is bounded by Arabian Sea with important natural resources of terrestrial and marine system.

Materials and Methods

Monitoring any high sensitive area by using remote sensing data is very useful to understand the contemporary process of natural resource conservation on both global and local scale. For the present study remotely sensed DEM (Digital Elevation Model) data and sea floor data was used in making demographic structure of the area. Open source global satellite DEM data was downloaded from United States Geological Survey website and global modified ETOPO5 seafloor data was downloaded from National Institute of Oceanography (NIO), India website. Gridded ETOPO5 data derived from National Geophysical Data Centre with the same resolution was used to modify ETOPO5 dataset to produce a better quality bathymetric dataset (Sindhu et al., 2007). Recent high resolution Google Earth's image was used as a base map and for validating various satellite information several times field survey with necessary procedure like GPS (Global Positioning System) survey, grab sampling, depth measurements, sediment and water quality analysis have completed of the respective area.

For analyze, extraction, digitization, identification, rendering of surface features as well as 3D TIN (Triangulated Irregular Network) model preparing and detailed site characterization for spatial planning in coastal areas, the ArcGIS software was used. Through the underlying processes of modeling in ArcGIS domain any spatial data can be represented by two dimensions (2D) or three dimensions (3D) visual way. Implementation of geo-visualization technology in coastal management with 3D model is increasingly used in spatial planning and to create that 3D model of crucial areas geographical data such as the DEM (Digital Elevation Model), aerial photography and satellite images etc. are used at present (Rolf Gabler-Mieck and Rainer Duttmann, 2007). In-situ collection of hydrographic parameters and substratum was done and analyzed following standard procedure (Strickland and Parsons, 1972; Grassholf et al., 1983; APHA, 1992).

Results and Discussions

Coastal area always has an environment of great dynamics and complexity because this is the only place where land, ocean and rivers meet and interact with each other. Any costal area can be classified according to its land uses, such as residential areas, industries, fisheries and aquaculture, trade and shipping and tourism compete and interact. In this paper the specific study area was categorized into four crucial and valuable zones based on the human and natural activities of that area along with the field survey conducted for identification of the sites for aquaculture. For successful coastal environmental resources management and planning of the terrestrial-marine interface, it is important to focus on categorization of coastal area in micro or macro level. In the case of coastal areas, GIS can be applied to balance in a variety of contexts including aquaculture, energy production, natural resources conservation, fishing, and recreation activities in coastal area.

Any spatial information like geo-coded field survey data, remotely sensed satellite DEM data or seafloor data can be mapped or modeled easily by ArcGIS software. As a result of the present process an exclusive 3D demographic structure of the study area was modeled with the respective layer based information in ArcGIS as shown in Fig 3. The 3D model structure was created using ArcMap and ArcScene components together, which helped to integrate all available spatial data the Z-value with respective methods like extraction, interpolation and 2D and 3D spatial analyses. It contains valuable information of the study area, future possibilities and scopes for using natural resources from the coastal area. This pictorial 3D representation gave more visual clarity to understand, analyze and plan the area in a better way.

A. Aquaculture Zone:

Aquaculture is one of the activities in coastal area which uses natural resources and depends upon its inputs and attendant processes to produce a final product for consumers and gain financial support for makers. According to Food and Agriculture Organization (FAO) aquaculture plays an increasingly valuable role in the global economy and fisheries has significant role in poverty alleviation and food security. For zoning near shore aquaculture, it requires the integration of the range of physical, environmental, and social parameters (Noelani Puniwai et. al. 2014). Aquaculture and its spatial information are of high demand for coastal managers to reduce any complex environmental and social issues regarding the location of the aquaculture sites. In this case study, aquaculture zone was mapped and modeled and categorized for various aquaculture activities such as prawn farms, small cage culture site, hatchery complex potential site, crab culture potential area, bivalve fishery etc. According suitability of water quality, water current, water depth and bottom sediments etc., availability of creeks within the mangroves belts were also taken as criteria of suitability of probable farming areas especially in the case of crab farming (Fig 3). Mangroves have a pivotal role in biodiversity compositions and marine fisheries resources management because it provides natural foods and protected shelters to marine species and their juveniles.

GIS has many advantages for aquaculture development programs. GIS is an essential guide to understand the role of spatial information in the sustainable development and management of fisheries and aquaculture (FAO Fisheries and Aquaculture Technical Paper 552). It is a broadly accepted fact that GIS analysis and GIS applications in aquaculture that relates to ecosystems is the most realistic resolution for projecting the valuable impacts of cage installation and cage culture (Dineshbabu et. al., 2014). Using GIS models and its applications to select aquaculture sites have been carried out in several papers earlier; Aguilar-Manjarrez and Ross in 1995, shellfish and finfish aquaculture in British Columbia, Canada (Carswell, 1998), hard clam culture and management in Florida, USA (Arnold et al., 2000), scallop growth and food depletion modelling in Sungo

Bay, China (Bacher et al., 2003), crab and shrimp cultivation in south-western Bangladesh (Salam et al., 2003), floating marine fish cage aquaculture in Tenerife, Canary Islands (Pérez et al., 2005) and oyster culture in Margarita Island, Venezuela (Buitrago et al., 2005).

B. Fishing Zone:

Identifying proper place for fishing in coastal area is very essential to develop that area in a better way for present as well as future. It helps to reduce any social and cultural issues between other activities zone of coastal area. RS and GIS have an important role in mapping, visualizing, analyzing all geographic and spatial aspects of costal area and its development and management. It has an impact role in identification of suitable sites for fishing zone. A suitable fishing zone is planned here according to sea depth and demographic structure of respective area (Fig 3).

C. Tourism zone:

A sustainable tourism zone helps to achieve the goal of economic development without damaging biological and ecological resources, where unsustainable tourism increases the tress of damaging natural resources in coastal area. For this study a proper place has identified as sustainable tourism zone (Fig 3) and the zone is suitable for any sports activities in water making tourist attraction like sea surfing, sea riding, marine driving etc. In earlier several case studies and papers have already revealed the utility and priority of sustainable tourism. GIS provides the advanced techniques with wide applicability for sustainable tourism development. According to Bas Boers & Stuart Cottrell, 2007, GIS is a decision support system for integrating socio-economic and environmental datasets in tourism and sustainable tourism development.

D. Water Transport Zone:

Transport is a function of moving objects from one place to another in the two dimensions of physical time and space. Water transport is one of the major communication modes in any coastal area. Any well planned and geo-reference marked area for water transporting is always valuable in developing coastal areas and its management. Similarly a water transport zone was identified in this study which avoids any obstacles for other zones in spatial planning the coastal area (Fig 3).

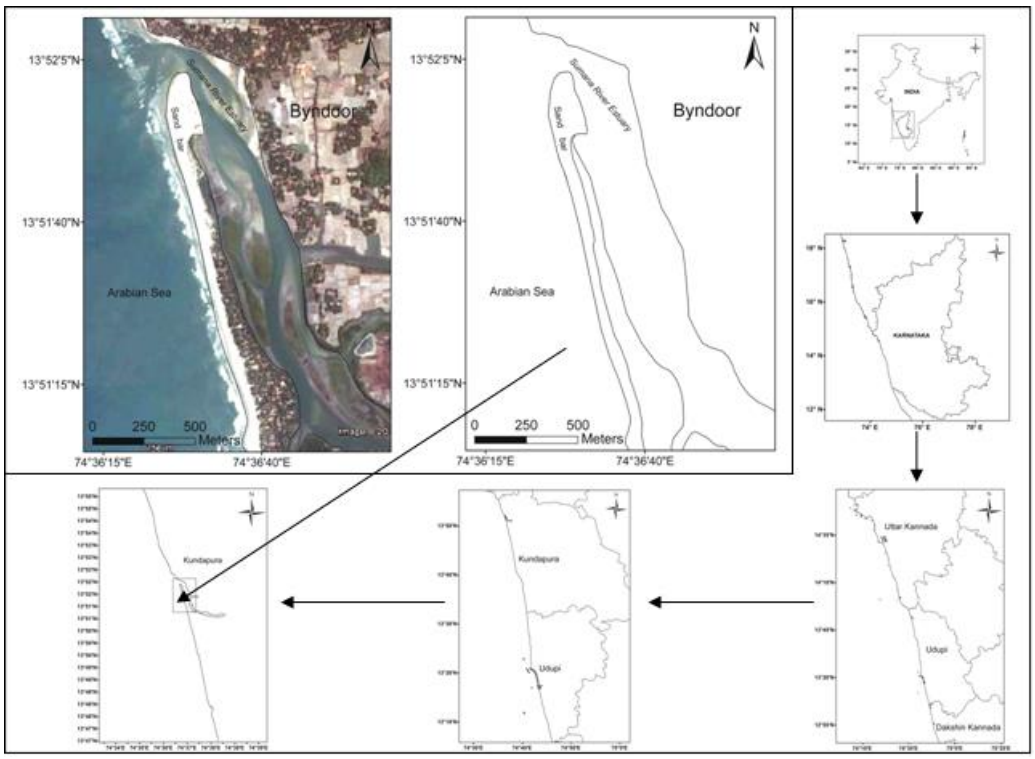
Conclusion

Indexing of geospatial data of coastal natural resources in India was done by using GIS techniques which demarcated the areas for various utilities and activities for sustainable use and management in present as well as future. The smart coastal zone management through mapping is an effective method to plan and execute the resource utilization along the coast. The planners and developers can rely on this type of categorization which is a ready reckoner and a desktop solution for sustainable management of the natural resources and issues related to its conservation. ArcGIS as very powerful and effective GIS tool to map the resources on a 2D or 3D. This spatial information helped in depicting the various uses of coastal ecosystem and human interfaces and also to project the possible interventions from that area in future. ArcGIS software is also valuable tool to make policies and decisions for economic development of coastal area in small or large scale because it helps in site selection, suitability analysis of the selected sites with geographic and scientific methods. Thus it can be concluded that the user friendly ArcGIS software has extended its application in the marine resource management and acts as a support system to make decisions and policies in coastal natural resource management.

Acknowledgement

The authors are thankful to Dr. A. Gopalakrishnan, Director, Central Marine Fisheries Research Institute, Cochin and Dr. Prathibha Rohit, Scientist-In Charge, Mangalore Research Centre of CMFRI for their support and suggestions. The authors owe gratitude to Space Application Centre, Ahmadabad, and Department of Space of India for funding this present research. The constant co-operation and help contributed by the fishing community of Byndoor, Karnataka are also thankfully acknowledged.

Fig 1: Location Map of the Study area



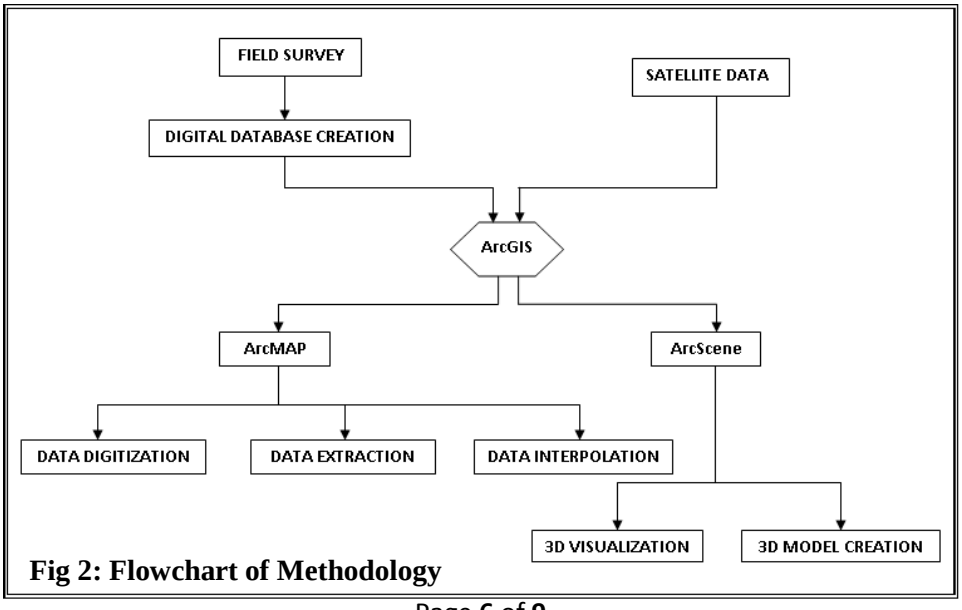
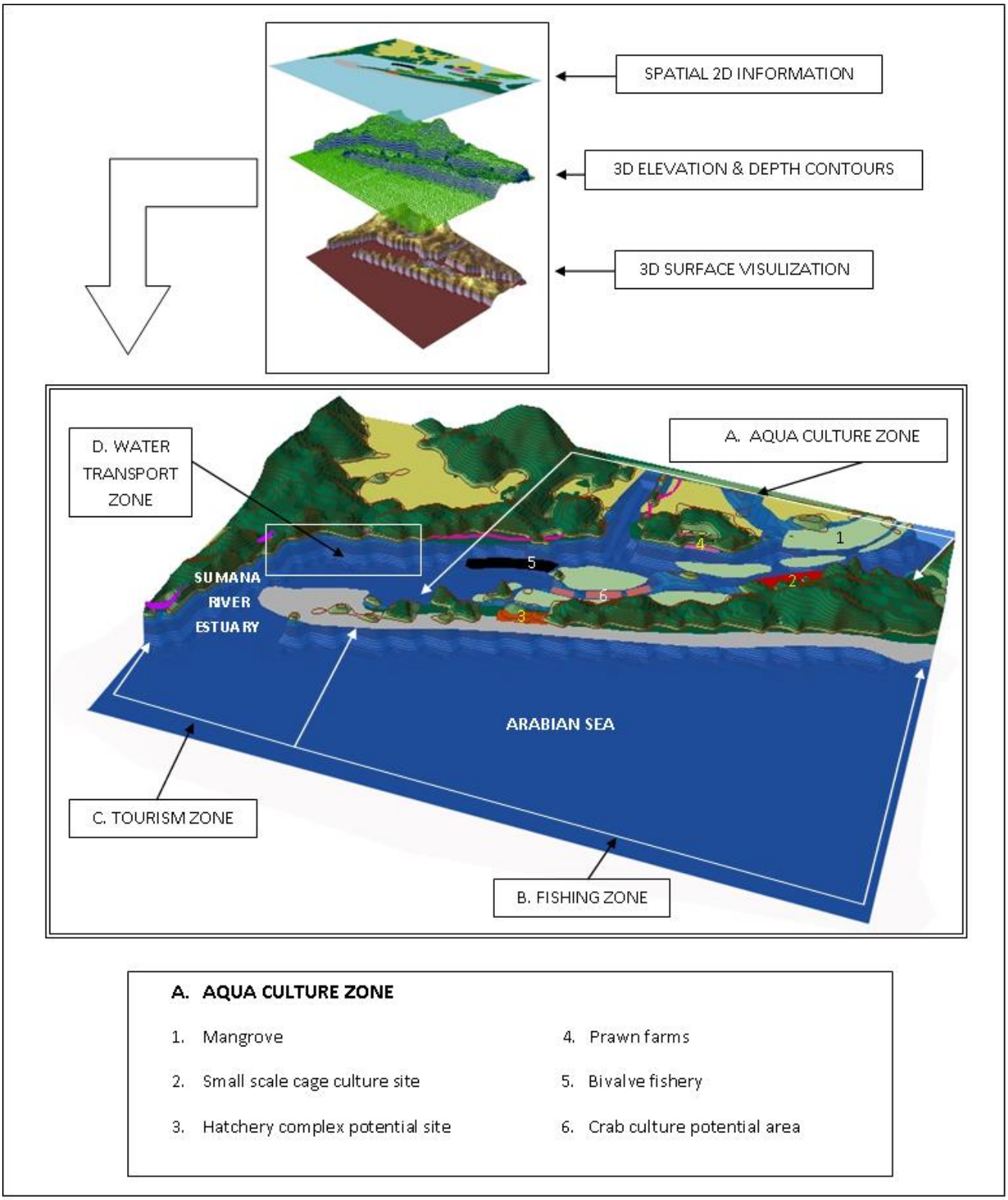


Fig 2: Flowchart of Methodology

Fig 3: Indexing of Coastal Zones according to its natural resources and demographic structure



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