investments, Multi National Campany ventures may help the utilization of space. Important areas should be studied in detail and preference be given to the project which boosts the internal economy the most. Thus, priority wise imple mentation in the above project areas can turn the state of Kerala into a major hub of foreign and multinational investment.

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APPLICATIONS OF GIS AND REMOTE SENSING TO INLAND FISHERIES AND AQUACULTURE

P.Mahalakshmi and K.Ganesan

INTRODUCTION

GIS and Remote Sensing (RS) methods have been used as successful planning and management tools. Remote Sensing data have been proven useful in assessing the natural resources and in monitoring the changes (Ratanasermpong et al., 1995). Remote Sensing technique is also a useful source of information as it provides timely and complete coverage of the study area, complementing field surveys of higher information content. A GIS can be considered as a Database Management System which allows users to store retrieve and manipulate data, integrated with a series of routines which allow sophisticated spatial analysis and display (Burrough, 1986).

Analyses performed with GIS can only be as accurate as the data sets used in the project. Data gathered via Remote Sensing is crucial to many fisheries and aquaculture applications of GIS, often due to the large geographic scale required to encompass the 'habitat' of a particular species, or attempts to correlate ocean patterns with species distribution. The RS data most frequently used in fisheries operations have come from the Advanced Very High resolution Radiometers (AVHRR) positioned on the National Oceanographic and Atmospheric Administration's (NOAA) weather-satellites (Simpon, 1994). Aquaculture has benefited significantly from the use of GIS and Remote Sensing in the recent years which jointly showed their capabilities in the evaluation and assessment of suitable sites for a variety of culture systems.

STATUS OF GIS USE IN AQUACULTURE AND FISHERIES DOMAIN

A fundamental factor causing slow growth in GIS use is concerned with the human organisational structure of fisheries, and especially in the fragmented nature of the activities. Thus fisheries research and management tends to take place in an array of types of institutions - universities, fishery management authorities, consultants, research institutions, etc. These are scattered world-wide, often in peripheral, seashore locations, and many institutions are either not conversant with GIS as a management or decision making facility, or they are too small to support such activities. In the literature there are not enough GIS related publications in the fisheriesdomain. They are more frequently published in the form of governmental reports or in other "grey literature" resources (Figure 1). The first GIS application in fisheries came in mid-1980, but little growth occurred until the 1990's. To date, GIS has been applied for regional, national or sectoral studies of aquaculture where human resources, specific sites, economics, markets and sociocultural resources have been considered (Kapetsky et al., 1988; Meaden and Kapetsky, 1991; Nath et al., 2000). A number of large-scale and sectoral studies have been carried out, for example, in Louisiana State, USA (Kapetsky et al., 1990), in the African continent (Aguilar and Nath, 1998; Kapetsky, 1994) and in Latin America (Kapetsky and Nath, 1997). Studies at national levels have included salmon and mussel cage, pen and bed culture in Chile (Krieger and Muslow, 1990), and salmon and rainbow trout farms in Norway (Ibrekk et al., 1993). A number of studies have further exploited the modelling capacity of GIS, including the development of a model for sitting salmon cage culture on the West Coast of Scotland; an exploration of the potential for rice-fish and fish culture in the Red River Delta, Vietnam (Tran and Demaine, 1996); regional development models for shrimp culture in Mexico (Aguilar, 1996), and crab culture in Dhaka, Bangladesh (Salam,et al 2002). A watershed pond aquaculture study has been carried out in Thai Nguyen, Vietnam (Yi et al., 2003). A comparative study has been carried out, for example, in Bangladesh (Salam and Ross, 1999; Salam and Ross, 2000; Salam et al., 2003). Site selection issues range from meso-scale decisions to very local ones. GIS models based on environmental and system conside rations have been shown to be an excellent tool for detailed facility location, once a preliminary choice of site has been made (Ross et al, 1993). In conjunction with remote sensing and direct data collection, GIS can also form the basis for continued monitoring of a site (Chacon-Torres et al., 1988, 1992).

ILLUSTRATIVE APPLICATIONS IN AQUACULTURE AND INLAND FISHERIES

The following case studies are intended to give as wide a review as possible of various examples of the practical applications of RS and GIS to aquaculture and inland fisheries.

PRESELECTION OF TROPICAL SHRIMP FARMING USING REMOTE SENSING IN NEW CALEDONIA

CNES-IFREMER (1987) group has identified the preselection sites for aquaculture in part of New Caledonia (Figure 2). Potential sites for shrimp production have been circled. Various image enhancement and enlargement processes would then be performed on the digital data covering these areas. In this case the criteria for site selection and assessment of potential involve complex considerations of meteorological, hydrological, geomorphic and socio-economic factors. The availability of real time and precise geographic data for identifying site potential is offered by imagery such as SPOT. This data can lead to exact locational positioning and to precise aerial quantification - a positive aid to decision-making. The digital form of this data allows for analysis under a huge array of circumstances, at selected scales varying from 1:20 000 to 1:400 000. IFREMER claim to have a selection of images for all tropical coastal areas available and since SPOT imaging has now been in progress for more than four years, temporal analysis of coastal developments are already possible. Where airborne sensing is notpossible, or where it is not easily available, then clearly the resolution achievable by SPOT is sufficient for identifying potential locations for shrimp culture. For understandable reasons, this promotional material fails to mention the additional potential which digitized SPOT imagery would have as source data for a range of more complex GIS investigations.

OYSTER CULTURE IN S.E. ALASKA, ETOLIN ISLAND AREA USING REMOTE SENSING

Cordell and Notle (1988) have used the scores of scale 1 to 4, with 4 representing the highest suitability of the parameter and 1 lowest, for prioritizing the factors (Size of area, Depth of water, Turbidity in the area, and Presence of sea ice, Shelter from high seas or current) that determine the suitability of a location for oyster culturing across the S.E.Alaska. The scoring, as applied to four sites which were selected to test the methodology, is shown in Table 1. It shows that, the areas around Blashke Island and Jadski Cove appear well suited for the development of oyster culture. The lack of suitability of the Stikine Strait area is well identified.

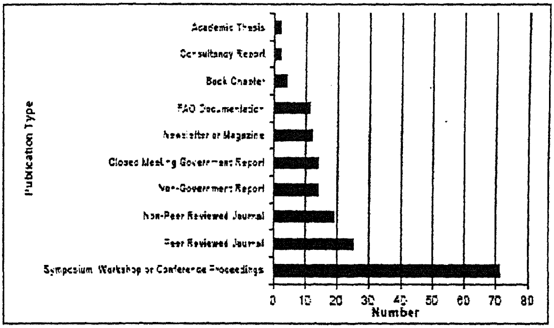

Figure 1: Publication Mode of 174 Fisheries GIS Related Works produced between 1984 and 1998 (from Meaden, 2000)

CATFISH FARMING DEVELOPMENT IN A FRANKLIN PARISH, LOUISIANA, U.S.A

Kapetsky et al. (1988) have created a GIS model to identify and inventorize areas of Franklin Parish, Louisiana, suitable for Catfish farming based on physical characteristics of soil like pond construction, levee construction, commercial buildings, local roads and equipment, and susceptibility to flooding. A second location criterion use was made of a map showing all areas with more than a 1% probability of flooding each year (100-year floodplain map). The soil map and the 100-year floodplain map were digitized.

An ELAS GIS software package was used for data processing. The suitabilities of soils for catfish farming were compared with the location of existing catfish farms and proximity to a processing plant. It also shows that half of the existing catfish farms are located in areas indicated by the GIS as being most suitable. Only two of the 40 farms are located in the least suitable areas.

TROUT FARMS LOCATION IN ENGLAND AND WALES, BRITAIN

In a study of Trout farms in England and Wales, Meaden (1987) has used GIS models based on the production functions (spatial variable and economic factors) to show those areas suitable for Trout farms (Figure 2). The following methods were used for identifying the area suitability for Trout farms:

- For mapping purposes the areas of England and Wales were divided into a grid of 10 Km^2 cells.
- A map was produced for each of the production functions.
- A "score" ranging form 0 to 10, was allocated to each cell according to its ability to provide for each production function.
- Questionnaire method was used for giving the weight to all the functions. Weightings varied from 0 to 6.
- Mean weight could then be established for each production function.
- The weighted production function score was calculated by multiplying the mean weight given to a function with the score allocated to that function.
- The aggregated weighted scores were calculated and in (Figure 2) areas of relative suitability for trout farms by 10 Km^2 cells are shown.

Table 1: Site selection matrix showing suitability for oyster culture

Site	Area Size	Mean Depth	Turbidity	Sea Ice	Shelter	Total Score
Blashke Island	3	4	3	3	3	16
Stikine Strait	2	1	1	3	1	8
Anita Bay	3	2	4	3	2	12
Jadski Cove	3	4	4	2	3	18
Factor Scoring						
1. Area Size:	1 = < 1 hectare					
	2 = 1 to 2 hectares					
	3 = > 2 hectares					
2.Mean Depth:	1 = < 5 meters or > 20 meters					
	2 = 20 to 15 meters					
	3 = 15 to 10 meters					
	4 = 10 to 5 meters					
3. Turbidity:	1 = moderate turbidity (summer)					
	2 = low turbidity (summer)					
	3 = slight turbidity (summer)					
	4 = no turbidity (summer)					
4. Sea Ice:	1 = winter sea ice					
	2 = possible sea ice					
	3 = no sea ice observed					
5. Shelter:	1 = occasional high seas possible: two sides protected					
	2 = rare high seas: three sides protected					
	3 = protected on four sides					

Figure 2 clearly highlights the suitability of central southern England for trout farming, with its favoured areas of chalk or limestone hills providing high quality water, of a uniform temperature and having a consistent flow rate, i.e. little variability. These areas also have good access to road transport, high agglomeration potential, reasonable land costs and they are not too far from the various market outlets. An analysis revealed that 32% of all farms were located in cells which were ranked as being in the top 10% in their suitability for trout farming.

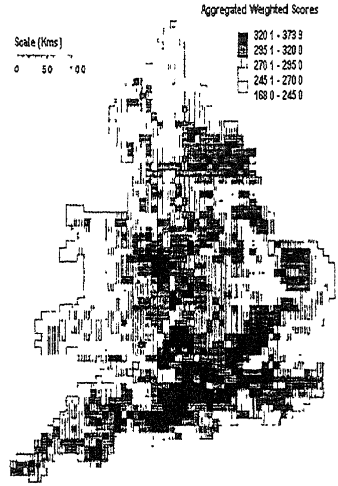

Figure 2: Areas suitability for Trout farms by 10 Km^2 cells.

MODELLING ENVIRONMENTAL SUITABILITYUSING SPREAD SHEET

The basis of GIS modeling can be simply illustrated in this very simple example in which a spreadsheet simulation was used to develop a simple GIS for carp culture in Pakistan (Ali et al., 1991). In this case seven environmental variables were used to indicate areas appropriate for carp culture on a macro-scale across the whole of Pakistan. The data for each criterion, in each grid cell, was scored on a scale of 1 to 5, with 5 representing the highest suitability of the parameter and 1 the lowest. The scored data was then entered into the spreadsheet package on a BBC-B microcomputer in a blocked layout which spatially represented the country. After the scoring of cells, a weighting was given to each parameter, according to how important it was seen to be. Weightings varied between 0 and 1. Scores were then multiplied by their relevant weightings and aggregated and the overall score obtained was thus a rating of the suitability of the cell for carp culture. The overall scores can be represented graphically using shaded blocks (Figure 3). It appears that the most suitable areas for carp rearing are in central-eastern Pakistan where many tributaries of the River Indus converge across a wide flood plain.

OPPORTUNITIES FOR SHRIMP AND CAGE CULTURE IN JOHOR STRAIT

Kapetsky (1989) has used GIS tool for locating further opportunities for shrimp farming in ponds and culture of fish in cages generally in the Johor Strait area. Data relative to site selection can be conveniently arranged into eleven categories for both farming and cage culture (Table 2). The data for each of these location criteria was assembled from a variety of sources. The data were entered, manipulated and analyzed using commercially available GIS.

Although about 193 000ha of coastal Johor is within easy reach of a water source for shrimp farming, only about 6% of this area includes soils which were rated "fair" or suitable in texture and pH. Most of these better soils are in the south and south-east coasts. In relation to the main criteria (Table 2) the west coast offers few opportunities for cage culture. Much of the south-west coast is too shallow, except in the mouth of the Sg. Pulai where cage installations could interfere with navigation. All of the Johor Strait area is well sheltered although only 12% of it has depths rated as good or fair. Water quality in the west Straits, and in the vicinity of

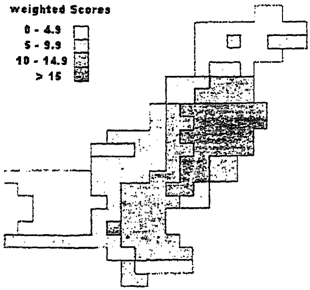

Figure 3: Graphic representation of cell scores showing suitability for Carp culture in Pakistan

Johor Baharu, is less well suited to cage culture than else where.

FRESHWATER FARMING LOCATION: CARIBBEAN ISLAND STATES

Kapetsky and Chakalall (1998) have described the potential for inland fish farming among the Caribbean Island States based on methods in an earlier study by Kapetsky and Nath (1997) to estimate freshwater fish farming potential in Latin America. Four criteria were used to estimate potential for small-scale fish farming in ponds: water loss, potential for farm gate

Table 2: Main criteria to identify opportunities for shrimp farming and for cage culture of fish in Johor state

Criteria	Shrimp Farming	Cage Culture
INFRASTRUCTURE: Primary roads, Secondary Roads, Cities and towns	X	X
WATER QUALITY TIME SERIES: Ammoniacal nitrogen, Biological oxygen demand, pH	X	X
WATER QUALITY AND LAND USES: District land uses, Agriculture, Urban, Mining, District Boundaries, Drainage basin boundaries	X	X
ANNUAL PRECIPITATION: Rainfall isohyets	X	-
SOILS: Hydrogen ion concentration, Texture	X	-
SHRIMP FARM SITES:	X	-
FLOATING CAGE SITES:	-	X
BATHYMETRY: Mudbanks, 2,5,10 and 20 meter contours	-	X
SHELTER: From the north within 2 km of coast	-	X
CURRENT SPEED:	-	X
SPOT DIGITAL DATA: 3 scenes covering part of Johor State	X	X

sales, soil and terrain suitability for ponds and availability of agriculture by-products as feed or fertilizer inputs. A fifth criterion was added in order to estimate potential for commercial fish farming: urban market potential. A map showing the spatial distribution of four categories of suitability: Very suitable (VS), Suitable (S), Moderately suitable (MS), Unsuitable (U) (Figure 4). The histogram shows the relative amount of surface area in each country corresponding to each category of suitability: Very suitable (VS), Suitable (S), Moderately suitable (MS) was presented.

The criteria were weighted in different ways to make small-scale and commercial fish farming models on the basis of expert advice. In this, the combined criteria was weighted by their relative importance —market size and proximity (49%), annual water loss (27%), soil and terrain suitability (13%), farm gate sales (6%) and potential for agriculture by-products (5%). Overall, most of the countries rate mainly VS, or S (Figure 5). This outcome is strongly influenced by the relatively heavy weights placed on market size and proximity and annual water loss.

Numbers of crops per year of Nile tilapia and common Carp were predicted based on monthly climatic variables. By varying feeding levels and harvest sizes small-scale and commercial level outputs were simulated. Combining the small-scale and commercial models with the simulations of fish production provided overall suitability ratings of five for each of minute (approximately 9 × 9 km). The results suggest good potential for freshwater fish farming among many of the Caribbean Island States with relatively large areas rating very suitable or suitable for the combined criteria and with relatively high crops/year output of the species considered. The results of the field verifications indicated the importance of local knowledge for the interpretation of the predictions.

DETAILED FACILITY LOCATION: SALMON CAGE CULTURE IN SCOTLAND

Data relevant to site selection can be conveniently arranged into four categories: the aquaculture system, the aquaculture species, and socio-economics and food safety/quality issues. The GIS readily permits alternative site-selection scenarios to be explored. For example, the key system and species data used by Ross et al. (1993) to determine suitable sites for salmonid cages were bathymetry, currents, and shelter and water quality. System decisions preceded species-specific considerations.

GIS AS A DECISION MAKING TOOL: FISH FARMING IN GHANA

Kapetsky et al. (1990) have designed a GIS based decision making tool for identifying the best opportunities for fish farming in Ghana. In this case seven parameters like water, land, favourable economic inputs and markets, welfare, availability of extension services, infrastructure and agglomeration were used to indicate areas appropriate for fish farming in the whole of Ghana. Each of the above criteria were weighted according to their estimated importance to fish farming, and then incorporated into the model. In order to portray a range of development opportunities, four integrated models were generated by applying different criteria combinations and weightings:A. Model K1 = KL + 0.5 (KI + KM + KW + KF)

B. Model K2 = KL + 0.5 (KI + KM + KF)

C. Model K3 = KL + KI + KM + 0.5 (KW + KF).

D. Model K4 = KL + 0.5 (KI + KM + (KF - AG)).

Where KL = the "Land and Water Index"; KI = Input indices (manures and rice bran).

KM = Marketing indices (population, fish consumption and distance to main markets.

KW = Welfare indices (incomes)

KF = "Other Factors Index" (aggglomeration, extension and development)

AG = Agglomeration indices only.

The results were output from GIS in three main forms. Maps identify the districts most suitable for development. Tabular data give the scores calculated for various criteria one at a time and together after they have been incorporated into models. Frequency distributions showing the number of districts against index values for each criterion or a combination of same. Looking at the "integrated models", showing a range of development opportunities, a variety of districts emerge as being potentially superior. Model K1 strongly favoured the central southern (Ashanti) area (Figure 4), and Model K2 strongly favoured the south i.e. it penalizes the north because the model omits welfare considerations which are adverse here. Model K3, which emphasizes the economic aspects rather than welfare, again shows much of the south to be favourable, though some of the north now benefits because of advantageous inputs. By excluding agglomeration, Model K4 highlights areas which would be good for fish farming, though at present it is little practiced. Clearly the provision of extension services here would be important. Again, southern areas are dominant.

SPECIES - SPECIFIC OPPORTUNITIES IN ARIZONA

Dennis McIntosh et al. (unpublished data) have designed a GIS based model to enable extension personnel, lad-use managers, farmers and other interested persons who may be unfamiliar with the specific requirements of aquaculture to evaluate potential farms sites in Arizona for aquaculture development and expansion. Data sets selected were grouped into four major areas: site suitability, water quality, and infrastructure and land ownership. Seven individual models were produced, one corresponding to each of the five most common Arizona aquaculture species (bass, catfish,marine shrimp, tilapia and trout) and two general models, designed to offer more flexibility in site selection. These non-species specific models allow the database to be queried by user-defined limits placed on the various parameters of the model and/or location (coordinates or city name). All data contained in the model were manipulated using ArcView GIS 3.2.

To test the model's predictive power, existing aqua culture farms were marked on a map generated by the model. Of the 31 farms depicted on the map, 21 occur in areas predicted to have suitable slope and sufficient soil clay content. Of the 10 that occur in areas not predicted as suitable, 5 have the correct slope, 3 have suitable soils and only 2 have neither.

Species-specific models were tested against the extant aquaculture facilities in the state. Of the five models tested, marine shrimp farms were most likely to occur in areas predicted as suitable by the model (67% correct). Bass, catfish and tilapia farm locations were predicted accurately 65%, 57% and 62% of the time, respectively. Trout farms were least likely to have their sites predicted as suitable by the model (27% correct). Figure 10 summarizes this information. Overall, the GIS based model was 56% accurate in its ability to predict the locations of licensed farms.

LARGE SCALE SPECIES-SPECIFIC SITE SELECTION: SHRIMP CULTURE IN SINALOA, MEXICO

In a large-scale study of shrimp farming potential in Sinaloa, Mexico, Aguilar (1996) has used GIS models based primarily on environment and infrastructure to show those areas suitable for agriculture and aquaculture. This large-scale site selection makes use of GIS models and species orientated specialist knowledge. The database of species specific information from which cut-offs for variables are extracted is effectively the core of an expert system, although implementation is not fully automatic. This aspect of application-oriented GIS is very important and requires close collaboration between GIS modeller and subject specialist. Clearly it is preferable if the subject specialist is GIS-literate and is the modeller. Not surprisingly, the best areas selected are in the coastal fringe and do coincide with established areas where shrimp culture is practiced.

By contrast, results from a study in Izmit bay, Turkey, where waters are polluted due to industrial and domestic discharge (Savasci and Ross, unpublished data) models, based on species, environment and aquaculture systemrelated data, revealed that very few sites

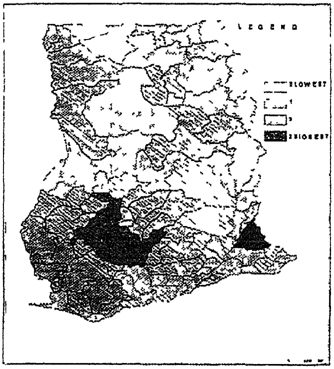

Figure 4: Fish farming potential in Ghana according to model K1

within this large region were suitable for culture of either the turbot Psetta maxima or mussels *Mytilus galloprovincialis*. Although the environment may improve in the future, current scope is clearly very limited. An area of only 725 hectares in the western part of the bay was classified as suitable for turbot culture and an area of 5,150 hectares in the western part of the bay was suitable for mussels.

LANDUSE OR LANDCOVER: IN KANDLERU CREEK AREA, ANDHRA PRADESH, INDIA

Hossain et al. (2002) have studied about the dramatic changes of landuse or land cover along with mush rooming of shrimp farms. Remotely sensed digital data sets acquired byIndian Remote Sensing Satellite in 1988 and 2001, topographic maps (1.50,000 scales, prepared by Survey of India) and published information regarding landuse/land cover practices were used as data basis for CDM method. Digital interpretation of all those data have identified 9 major landuse or land cover types in the study area (Table 3). Other information layers such as villages, roads, canals, islands, and swamps were also used as GIS layers. Finally, the analysis was carried out in Arcview GIS

COMPARATIVE STUDY FOR BRACKISH AND FRESHWATER SHRIMP AND FISH CULTURE IN SOUTH-WESTERN BANGLADESH

In a comparative study of brackish and fresh water shrimp and fish culture in southwestern Bangladesh, Salam and Ross (1999) have used a GIS model based on thirty environmental and economic criteria to select areas suitable for culture of brackish water shrimp, freshwater prawn and fish. In this study suitability ratings for each criterion was employed, and each factor was reclassified into a suitability layerscored on a 1 to 4 range. A weighting for each factor was then established according to the pair wise comparison matrix of Satty (1977). Using these weighting procedure eight sub-models were developed. Finally, three system oriented models were generated (brackish water shrimp, freshwater prawn and fish) by using different combinations and weighting of the modules. After creating the weighting procedure the MCE (Multi Criteria Evaluation) module of IDRISI was used for evaluating land allocation for freshwater fish and prawn (Fig 6 and 7) activities. It is clear from the two images that there are some areas in which activity conflicts will exist. This conflict was solved by MOLA (Multi Objective Land Allocation) tool of IDRISI (Figure 8). Weights for each activity were set to be the same to give them equal emphasis. A similar GIS model for the shrimp (Penaeus monodon) and mud crab (Scylla serrata) culture in Southwestern Bangladesh were discussed by Salam and Ross (2000) and Salam et al. (2003)

LAND - BASED AQUACULTURE PLANNING IN AUSTRALIA

In a land-based aquaculture planning in Australia McLeod et al. (2002) have used a sequential, two-stage approach for analysis of the data. The first stage, coarse scale preselection, eliminates the grossly unsuitable portion of the study area based on six major constraints with rules and low resolution data (Table 4). In this stage individual binary

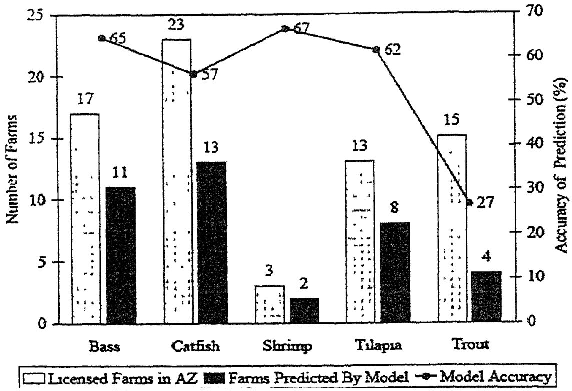

Figure 5: Graph depicting the accuracy of the five, species specific GIS models developed, showing the number of extent aquaculture facilities, the number of farms that fall in the redicted' area and the accuracy of each model.

Table 3: Landuse or land cover classes with distributed area derived in 1988 and 2001

Land use classes	Total area (ha)	
	LISS-II (1988)	LISS-III (2001)
SF - Active shrimp farms or shrimp farms with water	539.57	936.04
Dry SF - Harvested shrimp farms without water or drying of shrimp farms during pond preparation	-	2017.92
S_bar - Sand bar created in the creek mouth	22.8	24.98
WB - Water bodies (creek, reservoirs other than active shrimp ponds)	3230.14	2582.48
Forest - Terrestrial forest other than mangroves, agriculture fields and grasslands	4928.98	4371.48
Sveget - Small vegetation (grass field and agriculture field)	11194.81	12067.31
B_soil - Barren soil (basically without vegetation)	1853.09	2604.20
Mangr - Mangrove Forest	3708.88	1046.84
Unclass - Unclassified lands	186.01	13.03

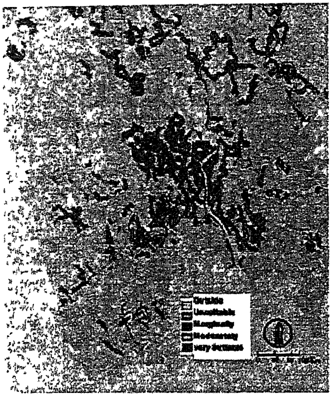

Figure 6: Suitable areas for fresh water prawn culture

constraint layer, for each constraint, by applying a predefined threshold to partition the spatial data layer into two classes, which were labeled suitable or unsuitable accordingly. This stockof constraint layers was then spatially intersected to derive a map of candidate shrimp farm areas that conform to the preselection constraint rules and excluded that were unsuitable. The second stage, Fine-scale analysis, then focuses on ranks the remaining area using ten constraints (Table 5) with high resolution data. Table 5 shows the results of one example fine scale analysis scenario identifying the percentage of areas of high (123ha), moderate (789ha), low (2578ha) and no potential (3538ha). Finally GIS was used to present the results of the analysis in an easily accessible form. This model was able to test the shrimp farm site suitability prediction against the location and performance of the existing shrimp farms in the fine-scale analysis of study area (Figure 9).

COMPONENT BASED GIS

Recent paradigm of software engineering tends to focus on developing component, which considers reusability and interoperability. Moreover, many GIS and Geo scientific tools are traditionally closed applications that are not compatible with each other. Their reuse for new applications is a nightmare due to poor documentation, heterogeneity in terms of data modelling concepts, data encoding techniques, access functionality, etc. Some vendors are starting to offer open interfaces based on standard "middleware" platforms like CORBA (Common Object Request Broker Architecture).The alternative to the "monolithic" GIS is open systems, which are based on component technology. Examples of component-based systems are MapObjects of ESRI, GeoMedia of intergraph and Autodesk World of Autodesk and OGC. The OGC is "the full integration of geo-spatial data and geo-processing resources into mainstream computing and the widespread use of interoperable geo-processing software and geo-data products throughout the information infrastructure" (Jo et al., 2002).

Most of the GIS applications need its common functionality such as mapping, 3D viewer and GPS data processing. Therefore, if there exists a universal repository storing GIS components and system designers or developers know where desired components are located in real time, they can easily select their desired component then modify or composite to their system by using them (H. E. J, 2002). Goddard et al. (2003) have developed a National Agricultural Decision Support System (NADSS) using component based distributed GIS. An important aspect of this system is accessibility of the tools to researchers, government workers, and farmers. The traditional three-tier architecture of Web-based GIS tools uses a proprietary interface to access these tools. Out of three layers namely data, information and knowledge, the data layer contains distributed spatial, constraint, andrelational databases. This layer provides transparent access to either local or remote data without concerning data formats.

The layer also provides a mechanism to encapsulate existing data interoperability solutions such as CORBA based or DCOM (Distributed Component Object Model) based Open GIS Consortium objects, or data access via the Open Geographic Data store Interface. In this project interoperability with ESRI's

Table 4: Constraints, rules, limits of resolution used in the coarse-scale preselection of sites considered for shrimp farming

Constraint	Rules	Resolution (m)
Study area	Mainland Australia within 10 Km of the coast	150
Distance to water	Distance to water <2 Km	160
Elevation	Elevation <20 m	200
Slope	Slope <5%	280
Not wetland	Not mapping as wetland	160
Not urban	Not within 3 Km of built-up areas	160

Table 5: Results of one example fine scale scenario identifying the percentage of areas of high, moderate, low and no potential

Constraint	Resolution (m)	High Potential	Moderate Potential	Low Potential	No Potential
Elevation	10	61	36	1	1
Slope	15	77	11	8	1
Distance to water	10	26	20		22
Texture	5	80	1		16
Parcel area	5	75	9		3
Current zoning	25	59	11	21	3
Strategic plans	25	59	38		
Agricultural land class	10	17	37	47	
Sugarcane suitability	25	19	7	43	
All constraints	-	2	11	37	50
Combined	-	123ha	789ha	2578ha	3538ha

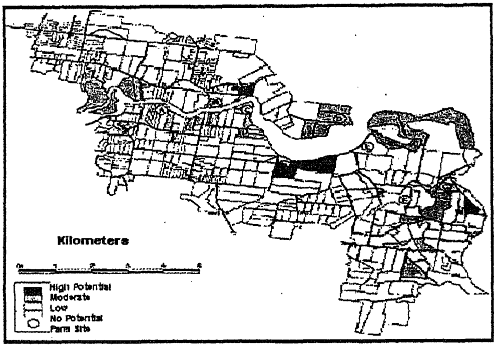

Figure 9: Results of example fine-scale analysis mapping shrimp farm site potential with locations of existing shrimp farms

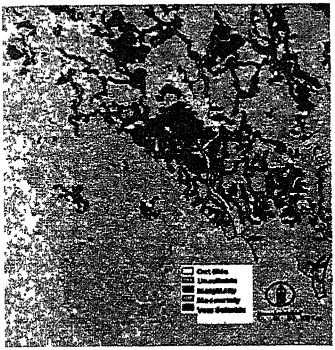

Figure 7: Suitable areas for fresh water fish culture

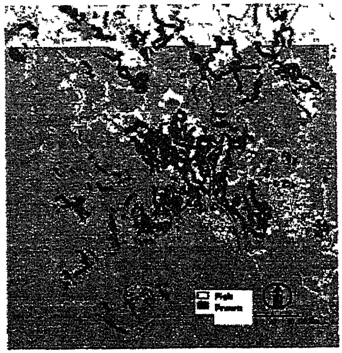

Figure 8: Suitable area for fish and fresh water prawn culture after using MOLA technique

ARCINFO and other GIS software is an important foundation for technology transfer for wider government and commercial applications.

CONCLUSION

GIS has been applied for regional, nationalor sectoral studies of inland fisheries and aquaculture where human resources, specific sites, economics, markets and socio cultural resources have been considered. Decision Support Tools (DESTA) which are developed (Stagnitti, 1998) to facilitate aquaculture management decision and design for new aquaculture facilities, are of great use in aquaculture and fisheries management at the farm as well as the regional level, but some of the desirable features such as re-use, exchange of data etc cannot be realized using such technologies.

The ultimate goal should be to provide a fully open system that would allow the aquaculturist to develop component based GIS applications to any aquaculture and fisheries environmental domain (Mahalakshmi, 2003). This is still considered to be very much a long-term ambition.

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ENVIRONMENAL CHANGES IN TUTICORIN COAST

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INTRODUCTION

Coastal environment plays a vital role in nation's economy by virtue of their resources, productive habitats and rich biodiversity. India has a coastline of 7,516 km and nearly 250 million people live within a distance of 50 km from the coast. The coastal zone is endowed with a variety of coastal ecosystems like mangroves, coral reefs, lagoons, sea grass, salt marsh, estuary etc. Coastal ecosystems are important for millions of people around the world as they provide subsistence. The coastal ecosystems are now highly disturbed and threatened due to rapid increase of population and developmental activities along the coast. In the state of Tamil Nadu, between the year 1988 and 1998, 25.56 km^2 of coral reefs and 2.16 km^2 of seaweeds were lost in Gulf of Mannar (Thanikachalam and Ramachandran 2002a, 2002b, 2002c and 2003). Between the year 1986 and 1993, 0.36 km^2 area of mangrove in Pichavaram was lost and nearly 2500km^2 of the mangrove werelost in entire India between 1986 and 1994 (Krishnamoorthy 1995). Apart from the anthropogenic activities, natural causes are also play an important roll in coastal environment changes.

The present study describes the coastal environment changes in Tuticorin coast using remote sensing and GIS techniques.

STUDY AREA

The coast of Tuticorin (Figure 1) a part of Gulf of Mannar Biosphere Reserve, is situated in between the latitude of 8° 45′ N and 9°02′31″N and the longitude of 78°07′17″E and78°19′18″E. This geographical area runs from the Mouth of Vaippar River to Tuticorin Harbor. The coast of Tuticorin encompasses 4 small islands located at an average distance of 4km from the mainland. These islands are built up of calcareous framework of dead corals and coral reefs. The area is endowed with a combination of ecosystem including mangroves, coral reefs, sea grass and seaweeds.

MATERIALS AND METHODS

To fulfill the objectives of this study, five types of approaches have been attempted, such as (i) interpretation of multi-date optical remote sensing data for detection and mapping of changes in coral reefs ecosystem, (ii) interpretation of multi-date remote sensing data for mapping and change detection in Coastal Land-use/Land cover, (iii) interpretation of remote sensing data for mapping the coastal landform, (iv) interpretation of multi-date remote sensing data for mapping and changes in shore line (iv) and analysis of the multi-date bathymetry data for sea floor changes.

Coral Reef Mapping

Geocoded FCC of IRS LISS-II (April 1988) and IRS LISS-III (May 1998) images on 1:50,000 scale were visually interpreted based on image characteristics, various coral reef categories in the Gulf of Mannar have been identified and mapped. In the present study, the classification system developed by Space Application Center for thenational coral reef mapping project (Anjali Bahuguna and Nayak, 1994) has been adopted. After identification and delineation, an accuracy test based on probability of