SUITABLE SITE SELECTION OF SHRIMP FARMING IN THE COASTAL AREAS OF BANGLADESH USING REMOTE SENSING TECHNIQUES (4 S MODEL)

Author(s) [(2)] **:**O. Quader. Z.Islam, H. Rahman, M.Rahman, M.H.Sarkar, A.Salam Khan
Bangladesh Space Research and Remote Sensing Organization (SPARRSO)
Agargaon, Dhaka-1207, Bangladesh

WG[(3)]**: Ths 19:** Integrated Coastal Zone Management

Keyword [(4)]: Suitable Site, Shrimp farm model, Coastal Zone, Bangladesh

Abstract

A study has been made on the Coastal Zone Development and Fishery Environment Analysis using Remote Sensing Techniques' in Bangladesh under a TCDC programme. It is funded by UN/ESCAP.SPARRSO and Space Application Center (SAC) Ahmedabad of Indian Space Research Organization (ISRO) has completed the study successfully. The aim of this project was to develop space technology based suitable methodology using remote sensing and GIS for coastal zone development and fisheries environment analysis in Bangladesh. Two sites in Bangladesh were selected for the pilot study, viz. Cox's Bazaar and Khulna-Satkhira. In the study various types of data have been used. It includes different satellite data, thematic maps, field-measured data and other relevant published information etc. Detailed and updated land-use maps have been generated for the two study sites. The whole work has been performed in six major parts: I) Construction of GIS based fisheries environmental database (GISFED). II) Selection, adaptation and test of GIS based Suitable Shrimp Farming Site Selection Model (shortly 4s model) III) Practical Implementation of 4s model IV) Application of shrimp suitability model and analysis of model generated output. V) Socioeconomic characterization of the study sites and analysis of the trend of shrimp culture development. VI) Analysis of environmental impacts of shrimp culture expansion and risk due to climatic events. VII) The result from the application of the model is comprehensive for some specific recommendations regarding the present state of the shrimp farming, as well as its future extension. Using this model it is found that, Khulna- Satkhira area are more suitable than Cox's Bazaar area for shrimp farming. Fishery resources have been successfully analyzed in the two study areas using GIS modeling of suitable site selection for shrimp farming. Tropical countries can use this model for allocating suitable site for shrimp farming by their Government for allocating shrimp farms in the coastal areas. This project report has been highly appreciated by ESCAP and ISRO India.

1.1 Introduction

Bangladesh is a vast delta having 14.2 million ha, of which roughly coastal brackish waters cover 17%. At present only 5% of the coastal brackish water region is under coastal aquaculture mainly for shrimp farming (Hossain, 1995). Gradually shrimp production is increasing through horizontal expansion of the farming area, not by the desired vertical expansion. However, a limited area under shrimp culture has created some environmental problems, which may lead to ecological disasters, as well as socio-economic problems of greater magnitude if proper measures are not taken. Therefore, careful planning is necessary to develop an environment friendly integrated coastal aquaculture program as a sustainable technique. So that, coastal aquaculture would develop as a good source of animal protein for the growing population, a foreign currency earner and as well as maintainer of ecological balances in the brackish-water region.

There is therefore an urgent need for sustainable development of the coastal resources, both for aquaculture/fisheries and agriculture. Monitoring of the changes and selection of suitable sustainable sites for aquaculture development is important in order to save the coastal ecosystems. This requires I) detailed survey and monitoring of the present situation, and, ii) exhaustive database creation, and, iii) modelling for sustainable development for brackish water aquaculture, agriculture, etc.

Sustainable aquaculture development and planning requires comprehensive data on landuse, water, economic and human resources available in a given area and synoptic integration and analysis of these resources. Remote sensing technique coupled with GIS are gainfully used or such a comprehensive analysis which lead to identification of suitable aquaculture site. So, it is necessary to conduct detailed surveys of the estuaries, brackish water, mangrove and mudflats for developing coastal aquaculture using remote sensing technique.

By using remote sensing technique and GIS, the advantage is not only in time and cost effectiveness but also in achieving a more comprehensive and integrated treatment of aquaculture development criteria, which is difficult through conventional techniques alone (Kapetsky et al. 1987). Satellite remote sensing technique is being used as a tool to know location, extent and spatial and temporal changes of coastal fisheries, especially coastal shrimp farming area (Populas and Lanteri, 1991) Krishnamurthy et al. (1996) explained it for Tamilnadu Coast and Nayak et al. (1995) explained it for West Bengal and Gujarat coast. Shahid et al. (1996) explained it for Bangladesh coast. Considering this entire works, an attempt is therefore made here to use advanced remote sensing and GIS technique to identify suitable site for shrimp farming in the study areas of this project with much more accuracy and precision using latest technology. Studies have also been carried out at SPARRSO on various other aspects of coastal zone environment using remote sensing technique (Quader, 1986; Choudhury, 1992; Jabbar, 1994).

1.2 Objectives: One of the main objectives of the project is to develop a model for Selecting Suitable Site for Shrimp farming in the Coastal areas of Bangladesh Using Remote Sensing Techniques. It is funded by UN/ESCAP and implemented under a TCDC programmed with Bangladesh Space Research and Remote Sensing organization (SPARRSO) and Indian Space Research Organization (ISRO).

2. Description of the Study Area

Site 1:Cox's Bazar: 21°25'-22°00'N, 91°50'-92°15'E.***Site 2:*** Khulna-Sathkhira: 22°15'-22°45'N, 89°00'-89°30'E.

3.1 Data Used: In the present study various types of data have been used. It includes different satellite data (IRS, SPOT, Landsat TM), thematic maps, field-measured data and other relevant published information etc. The thematic maps on soil, land-use, land capability associations and soil salinity were used for the study. The land-use and land capability information is updated using IRS LISS III and PAN data.

3.2 Software Used: In the present study, the following software's were principally used:

- ERDAS Imagine V 8.3.1 digital image processing software integrated with the additional vector module.
- Arc/Info GIS has also been used for the GIS related part.

The use of Imagine and Arc/Info GIS provided an effective tool for the present work.

4 Methodology : In this section, methodologies used for the general operation during the present study have been described. However, detail descriptions for more specific operations have been provided in the respective chapters.

4.1 Geometric Correction and Processing and Classification of the Digital Images

Digital data of LISS III and PAN for Cox's' Bazar were downloaded using PC based ERDAS software available in SPARRSO. All the images were geometrically corrected and were projected to LCC system. IRS LISS, III and PAN images were re-sampled to 6-m spatial resolution in order to merge them with reasonable accuracy.

In the present work, both supervised and unsupervised methods of classification have been employed. The unsupervised method of classification is based on ISODATA algorithm available in the ERDAS Imagine software. While, the supervised classification method based on maximum likelihood algorithm has been used.

4.2 Preparation of Base Maps: Remote sensing application in various aspects of aquaculture has been demonstrated by Loubersac (1985) who used simulated SPOT data to demonstrate the capabilities of a high-resolution (10-20 m) data for aquaculture siting. A Geographic Information System (GIS) approach has recently been demonstrated through integration of ground and satellite remote sensing data to identify area suitable for aquaculture development etc. So, coastal wetland and landform mapping on 1:50,000 scale using satellite data for the two study areas of the coastal zone (i) Cox's Bazar Area (ii) Sathkhira-Khulna has been prepared as per the package development of the project. These maps provide information at the reconnaissance level and used as reference map for field survey/verification and creating GIS layers on the monitor.

4.3 Techniques used to obtain macro-structured land use classes in vector form:

- Unsupervised classification of merged image as well as LISS and TM image.
- Merging the classes to the desired number of classes.
- Elimination of non-homogeneity and noise using 7×7 majority spatial filter.
- Elimination of very small clusters.
- Raster to vector transformation.
- Combination of vector layers obtained from all the images.
- On-screen editing of the vector data.
- On-screen editing of the vector layer was needed to correct classification error, as well as to well shape the structures of the features. Micro-structured features were digitized on-screen from the images, as well as from the base maps.

4.4 GPS based field survey: Extensive GPS based field works have been carried out over the two study sites in support of the satellite-derived information for their correction and validation. The infrastructure information is also been updated by such survey. In addition, the model-derived outputs are verified in some specific points over the study sites.

5. Construction of GIS Based Fisheries Environmental Database (GISFED) for Suitability Analysis

Land surface processes have become a great concern in the context of global change and massive environmental degradation in different parts of the world. The human intervention to nature and earth's natural resources largely modifies the composition and properties of the earth's surface and its atmosphere. Specifically, the ever-increasing human population resulted in over exploitation of natural resources and thereby, causes irreversible damages to such system. These activities often provoke various environmental and ecological problems the world over. Massive destruction of forests, intrusion of salinity, and rejection of chemical pollution through urban and industrial activities degraded our environment alarmingly. The scale, intensity and persistence of such undesirable changes are highly variable over time and space.

To avoid further degradation of the earth's environment and to keep it in a livable condition such activities should be limited. Efficient planning and management effort with sustainable schemes should be coupled with the development activities. As such, understanding and monitoring of these processes become an urgent need requiring up to date and regular information over a given geographical area. In such context, creation of a spatial database is very essential for monitoring the characteristics of the on-going processes and changes. It is now well recognized that an efficient database must be established for the development and efficient management of a given region.

5.1 Generation of Database: The creation of spatial database in accordance with the GIS execution steps designed for the model is an important step for the implementation of the present project. The spatial data has been synthesized from different sources having different resolution, projections and feature types. Due to this, multi-dimensional spatial mismatching has been occurred during the synthesis of the database. In order to minimize these mismatching, a common reference frame was created based on extensive GPS survey in each of the study areas. The reference frame was first used to geometrically correct the land use map (since its feature resolution is comparatively higher). The other maps (soil parameters, elevation, etc.) were then corrected based on the land use map. Table 5 shows a listing of the sources of data and other related information used for creation of spatial database.

Comprehensive databases have been generated for the two study areas. The databases have been archived as vector layer, and can therefore be produced as map at selectable scale. The components of the databases have already been mentioned in earlier sections. The geographic and feature accuracy of the databases are high because of the extensive field verifications / surveys using GPS. These databases can be used for any applications.

A detail description of the model can be found elsewhere (Gupta, 1993). In the present study the parameters considered for selection of suitable site for shrimp culture are the followings:

Engineering Parameters: Topography (GIS), Elevation/Tidal amplitude relationship, brackish water supply

Ecological Parameters: Water salinity (Attribute) Data, Water pH (Attribute) Data, Water
Temperature (Attribute) Data, Soil type (GIS), Soil pH (GIS), Seed Availability as Hatchery (GIS), Impact of industry and agriculture on water quality (Attribute)

Infrastructure: Railway/Road network (Distance, GIS), Marketing Facility (Distance,
GIS), Processing facility (Distance, GIS), Power facility for pumping (Distance, GIS), Drainage facilities for Exchange of out Water (GIS), Other facilities (Bank, Education, Health, Fish Co-Operative), (Attribute) Data

Demographic parameters: Peoples economic condition: % of population having income 420Taka/Capita, SITE development (Attribute), Training facility (Attribute),

Meteorological Parameters: Annual Rainfall (Attribute), Evaporation Rate (Attribute), Air temperature (Attribute), Wind speed (Attribute), Storm/Dust Frequency (Attribute).

Table 7.Areas under each of the classes based on weightage for different polygon-based model parameters.

Class Based on Weightages	**Areas (Hectares)**							
	Soil-type		**Soil-pH**		**Topography**		**Elevation/Tidal Amplitude**	
	Cox's Bazar	**Khulna-Sathkhira**	**Cox's Bazar**	**Khulna-Sathkhira**	**Cox's Bazar**	**Khulna Sathkhira**	**Cox's Bazar**	**Khulna Sathkhira**
0	-	-	91315	-	109	-	21252	2843
1	6130	-	19888	15323	46479	-	2022	-
2	84314	3340	33065	63265	18111	-	10265	411
3	35089	66356	3623	73136	73383	-	23868	6794
4	22502	99159	149	17131	9953	-	85685	15141
5	-	-	-	-	-	-	322	93455
6	-	-	-	-	-	-	-	73237

Note: - Ranges of the parameter values for each of the classes are given in section 7.1.

- Areas in class 0 are unsuitable part of the study areas considering the values of the Parameters.
- Weightage of topography in Khulna-Sathkhira area belongs to a single class.
- Data on soil-type and soil-pH of mangrove forest areas in Khulna- Sathkhira are not available. Area statistics for these two parameters, therefore, do not include these areas.

6. Model Based Suitability Analysis of the Study Sites and Assessment of the Present Status of Coastal Shrimp Farm Areas

The suitable shrimp farming site selection model (4S Model) described earlier has been executed in a GIS environment to analyze the suitability of the two study sites. Such an operation results in maps of two study sites indicating the suitability values. A significant variation is observed in different places over the study sites. A total of 24 parameters have been considered in the calculation of suitability of the area. In the following section an area-based analysis has been presented.

6.1 Cox's Bazaar study area: The results from the application of the model are comprehensive for some specific recommendations regarding the present state of the shrimp farming, as well as, its future extension. Figure 12 shows the suitability map obtained from the application of the GIS model. The red polygon is the model application area. Comparing to the land use map (figure 2) this map is readily understandable for validation of the model as well as for future extension of the shrimp farming in this area. However, the statistics of the suitability map in table 8 gives quantitative values in this respect.

In table- 8, the number of suitability classes is nine. The first suitability class has a weightage of 67.9% and the last (ninth) class has the same of 45%. This indicates the wide variation of suitability of the land parcels for shrimp farms in this study area. The first suitability class has very low percentage of area; the second class has comparatively higher area, but still considerably lower than the other classes except the last two (eight and ninth). Thus, it is evident from the percentage weightages of the majority of the classes (third- seventh) that the land parcels under suitable class are moderately suitable in this study area.

In table-9, existing shrimp beds are seen to be placed to the higher suitability classes (first-fifth) with considerable higher percentage than they are placed to the lower suitability classes (sixth-ninth). This indicates the validity of the model in selecting suitable shrimp farming sites. For agriculture land, the situation is reverse then the shrimp bed: they are placed to the lower suitable classes with comparatively higher percentage. More or less similar situation as of agriculture land is seen for fallow land. For rest of the land use classes no specific pattern of suitability is seen.

Total areas of the six land use classes under model application are 75,227 hectares (table 5, rejecting the masked areas). About 38.6 % of this area (29,020 hectares, table 8) is placed to suitable classes. Total area of the land use classes other than existing shrimp and shrimp-cum-salt beds that are placed to higher suitability classes (first- fifth) is about 9,495 hectares. This area is about 126% of the existing shrimp bed area (7,517 hectares, table 5). It is therefore evident that high potential of the extension of shrimp farming exists in the area under model application. However, majority of this extension area belongs to the agriculture land (55.2%, table 9). Therefore, consideration for environment impacts of this extension should be given due importance.

Table 8. Statistics of the classes in suitability map for Cox's Bazar study area.

Suitability Classes	Weight age (%)	Number of polygons	Area (hectares)	Percentage of total suitable area
1	67.90	11	198	00.68
2	64.81	47	1482	05.11
3	62.34	132	4280	14.74
4	59.87	203	4942	17.03
5	57.41	199	5764	19.86
6	54.94	271	6911	23.81
7	52.47	173	2939	1013
8	50.00	97	1269	04.73
9	45.06	177	1235	04.25
Total	-	1318	29020	-

Table 9. Area and percentage of suitability classes in different land use classes of the Cox's Bazar area.

Suitability Classes	Tidal flat		Salt bed		Shrimp bed		Agriculture land		Fallow land		Shrimp-cum-salt bed	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1			17	8.69	132	66.08	44	22.38	5	2.37	-	-
2	52	3.51	17	1.15	811	54.71	574	38.76	14	0.94	13	0.91
3	30	0.71	799	18.68	1172	27.37	2103	49.14	175	4.09	-	-
4	116	2.34	1012	20.47	1950	39.46	1582	32.01	82	1.64	199	4.02
5	298	5.15	1629	28.27	2501	43.41	805	13.97	143	2.84	386	6.70
6	321	4.54	1027	14.54	148	2.09	5176	73.35	261	3.69	124	1.75
7	60	1.49	500	12.42	49	1.21	2118	52.62	1199	29.78	90	2.23
8	-	-	396	37.71	30	2.76	558	53.14	64	6.09	2	0.18
9	2	0.17	301	24.41	28	2.19	792	64.15	113	9.08	-	-
Total	879	3.53	5698	22.89	6821	27.39	13752	55.24	2056	8.25	814	3.27

Note: - Areas are in hectares.
- Percentages (except total) are based on total suitable areas under each suitability class.
- Percentages in total are based on total suitable area under all suitability classes.

6.2 **Khulna-Sathkhira study area:** Figure 13 shows the suitability map obtained from the application of the GIS model. Table 10 presents the statistics of this map. In table 10, the number of suitability classes is nine. The first suitability class has a weightage of 77.78% and the last (ninth) class has the same of 54.32%. The first suitability class has very low percentage of area (1.82%).

Table 10. Statistics of the classes in suitability map for Khulna/Sathkhira study area.

Suitability Classes	Weightage (%)	Number of polygons	Area (hectares)	Percentage of total suitable area
1	77.78	77	2356.22	1.82
2	74.07	859	33276.27	25.70
3	70.37	1890	53392.59	41.24
4	67.9	1385	29815.41	23.03
5	65.43	416	6707.16	5.18
6	62.96	96	1031.64	0.79
7	60.49	118	1088.99	0.84
8	58.02	110	1380.38	1.06
9	54.32	23	403.56	0.31
Total		4974	129452.22	

In this study area, the lower suitability classes (fifth-ninth) have very lower percentage of areas than the higher suitability classes (second-forth) except the first one. Thus, it is evident from the percentage weightages of the classes with higher percentage of area (second-fourth) that the land parcels in this study area are highly suitable with in the attained suitability classes.

Table 11. Area and percentage of suitability classes in different land use Classes of the Khulna-Sathkhira area.

Suitability Classes	Shrimp bed		Agriculture land	
	Area	**%**	**Area**	**%**
1	2205.78	93.62	150.44	6.38
2	26593.29	79.92	6682.97	20.08
3	35747.35	66.95	17645.23	33.05
4	7070.62	23.71	22744.78	76.29
5	318.68	4.75	6388.48	95.25
6	187.07	18.13	844.57	81.87
7	217.90	20.01	871.09	79.99
8	45.83	3.32	1334.54	96.68
9	-	-	403.56	100.00
Total	72386.54	55.92	57065.68	44.08

Note: - Areas are in hectares.
- Percentages (except total) are based on total suitable areas under each suitability class.
- Percentages in total are based on total suitable area under all suitability classes.

In table 11, existing shrimp beds are seen to be placed to the higher suitability classes (first-third) with considerable higher percentage than they are placed to the lower suitability classes (fourth-ninth). This, like Cox's Bazar study area, indicates the validity of the model in selecting suitable shrimp farming sites. For agriculture land, the situation is reverse then the shrimp bed: they are placed to the lower suitable classes (fourth-ninth) with comparatively higher percentage.

Total area of the two land use classes under model application is 1, 34,179 hectares (table 6). About 96.47% of this area (1, 29,452 hectares, table 10) is placed to suitable classes. Total area of the agricultural land is about 59,065 hectares; 96.6% of this area (57,065 hectares, table 4) is placed to suitable classes. This indicates the existence of high potential of the extension of shrimp farming in this study area.

6.3 Comparison of the two study areas in respect of suitability of shrimp farming

Comparing tables 8 and 10, it is seen that wide variation of suitability exists in both the Khulna-Sathkhira (77.8% - 54.3%) and Cox's Bazar (67.9% - 45.1%) study areas. Considering the percentage of weightage, Khulna-Sathkhira area is more suitable for shrimp farming than Cox's Bazar area. With in the attained suitability classes, majorities of the Khulna-Sathkhira areas are placed to the highly suitable categories (table 10), where as, Cox's Bazar areas are placed to the moderately suitable categories (table 8).

Total suitable areas in Cox's Bazar and Khulna-Sathkhira study areas are 29,020 hectares and 1, 29,452 hectares respectively. These areas included existing shrimp area, as well as, other land use classes considered for evaluation of suitability of shrimp farming. However, in both the study areas, high potential of extension of shrimp farming exists. Considering the higher suitability classes, 9,495 hectares in Cox's Bazar area (table 9) and 53,612 hectares in Khulna-Sathkhira area can be extended for shrimp farming.

7. CONCLUSION

Coastal aquaculture contributes a small part to the gross domestic product (GDP) of Bangladesh, its role as foreign exchange earner is of considerable significance. Though coastal aquaculture particularly that of shrimp farming creates job opportunity for rural poor, develops better communication system and brings electricity to remotest part of the country, but it has little to do with supply of animal protein to the vast malnourished population. Bangladesh is a vast delta having 14.2 million ha of which roughly coastal brackish water regions cover 17%. At present only 5% of the coastal brackish water region is under coastal aquaculture mainly for shrimp farming. The present status of coastal aquaculture problems created and encountered for its expansion have made it necessary to take appropriate measures for ensuring development of this sector. Correct planning, regulation and motivation are needed to develop an environment friendly coastal aquaculture program to avoid ecological disasters in a land scarce and densely populated like Bangladesh. This model will be very helpful to overcome this problem. Different tropical countries can use this model for allocating suitable site for shrimp farming by their Government.

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