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A review on applications of geographic information system (GIS) in fisheries and aquatic resources

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Abstract
GIS is a technology that can be applied to clarify issues, leading to solutions by treating several spatial components simultaneously. GIS has been used in aquaculture studies for the past 15 years to evaluate the suitability of coastal areas for farming activities. Aquaculture management issues such as the multiple uses of estuarine waters, studies relating to the impact of water quality on finfish and shellfish aquaculture, and habitat availability can be studied using GIS. Generally encountered issues between aquaculture operations and marine waterfowl habitats have also been addressed using GIS. FAO has established a web-based portal, GIS Fish, which can obtain the global experience on Geographic Information Systems (GIS), Remote Sensing and Mapping as applied to Aquaculture and Inland Fisheries. Several studies have been implemented on wetlands by giving importance to its conservation and management aspects, and positive results were obtained.

Keywords: GIS, Remote Sensing, Geospatial, PFZ, Wetland, Fisheries

Introduction
Geographic Information System (GIS) is a tool for making and using spatial information, and it is mainly concerned with the location of the features as well as properties/attributes of those features. It helps us gather, analyze, and visualize spatial data for different purposes. By recording their coordinates, a GIS quantifies the locations of features, which are the numbers that explain the position of these features on Earth (Shelton, 2018) [9].

Due to the difficulty in attaining spatial data on organisms/habitats in underwater environments, GIS was not a practical source of analysis in the past. When GIS, combined with other analytical tools and models, it allows for improved spatial monitoring and studies and, eventually, better and more effective management practices (Subhendu, 2013) [14]. Biologists have been able to track fish species and create databases with the advancement of radio telemetry, hydro acoustic telemetry, and side-scan sonar, and it incorporated into a GIS program to create a geographical representation.

Why GIS is important in Fisheries?
Fisheries planning and management have many spatial components and severe issues. Spatial components are movements and migrations of resources; the definition of fishing grounds, transportation networks, markets, and habitat loss, and environmental degradation can be grouped into spatial issues. Therefore, Fisheries biologists, Aquatic resource managers, and decision-makers have to address the problems of serious difficulty, especially in developing countries. By the way, GIS is a technology that can aid in clarifying the problems and lead to solutions with the help of many spatial components. However, many people are still unaware or afraid of the technology and its potential for fisheries management. GIS has been used in aquaculture studies for at least 15 years to evaluate the suitability of coastal areas for fish farming activities (Simms, 2002). Aquaculture management issues such as the multiple uses of estuarine waters, the impact of water quality on shellfish leases, aquaculture, and habitat availability, and conflict issues between aquaculture operations and marine waterfowl habitats have been addressed using GIS (Simms, 2002). By using GIS, intertidal areas (mudflats) were evaluated for the development of brackish water aquaculture (shrimp farming). The data were used for the analysis of site selection in India with the basis of some crucial parameters under six significant categories, i.e., engineering, water quality, soil quality, infrastructure facility, social restriction, and meteorological parameters (Karthik *et al.* 2005) [5].

GIS as a management tool: Monitoring and analysing spatially-distributed factors such as resources abundance and composition, feeding and reproduction, nurseries, fishing efforts, harvest, tagging and recaptures, recruitment, regulatory zoning, control and surveillance, conflicts between gear and fleets, ecosystem conditions, etc. pose significant operational and management challenges to fisheries. The essential usefulness of GIS lies in its ability to manipulate and overlay data in several ways and to perform many analytical functions so that it can contribute to a faster and more efficient decision-making process in fisheries. (Subhendu, 2013) [14].

FAO has recently released a web-based portal, GIS Fish, which can obtain the global experience on Geographic Information Systems (GIS), Remote Sensing and Mapping as applied to Aquaculture and Inland fisheries.

Application of Remote Sensing and GIS in Fisheries

- **Site selection for aquaculture or mariculture:** This is an original use of GIS in fisheries-related work. For any successful aquaculture activity, a suitable site is a pre-requisite. An optimal aquaculture site aids in better management of the aquaculture resources, and it ensures the sustainability of the farming activity. There are many criteria, guidelines, and essential factors for the selection of a site for aquaculture such as the topography of site, slope of land, water flow, volume availability, water quality, weather parameters, access and location of utilities, legislation concerning water rights, etc. helps in the decision making process. GIS gives the best platform to combine all this information and identify the areas that qualify the optimal set of parameters, which would be the best-suited areas for aquaculture (Shelton, 2018) [9].
- **Modeling fish activity and movement:** These applications area is just getting underway. Here the aim is to attach numerical models to a GIS to simulate, describe, or predict a range of processes. Examples include – movement models.
- **Analysis of fisheries catches and effort:** Fishery managers are interested in where fishing effort is concentrated; how much fish is caught where; what is the relationship between catch and effort, etc., and much exciting work is now being produced. Statistical output can be obtained from many GIS programs. Catches can be explained in terms of various environmental parameters or terms of fish life cycles.
- **Matching fish distributions to environmental parameters:** It will be of the utmost interest for those working in fisheries management or science to know the relationships between fish distributions and various environmental parameters. The types of parameters being commonly used include water temperatures (especially thermal fronts), upwelling indices, water depth, marine chlorophyll abundance, bottom sediment type, and salinity.
- **Establishing regional and national fisheries databases:** Although not directly a GIS application to fisheries management, it is clear that without substantial data inputs, then fisheries GISs could not function. So in some major fishery regions, a massive effort has gone into establishing databases, metadata sets, and in setting up regional data centres, e.g., in eastern Canada or at the various World Data Centres. Fisheries related data sets are slowly becoming accessible over the Internet.
- **Identification of potential fishing zones by remote sensing:** Remote sensing of ocean color is the only approach to provide a synoptic view of the abundance of the marine autotrophic community, which is at the basis of the marine food web. Areas with high phytoplankton biomass, as well as temperature fronts, have been related to increased abundance in fish. An Indian program, forecasting Potential Fishing Zones (PFZ), provides this useful information, free of charge, three times a week to artisanal fishers to increase their fishing efficiency and reduce their use of fuel. The locations of the PFZs are distributed to the fishing community through different media, in many cases, in the local language to facilitate the use of the information. Results strikingly show the benefits of using PFZ information, with a significant increase in fish catch and a reduction in search time. When the dissemination of the PFZ information is interrupted in areas (known as nurseries) and at time spawning peaks are identified; therefore, there is a need for the generation of a responsible fisheries forecasting program.
- **Applications in habitat mapping and change detection:** The advantages of remote sensing, like synoptic view, multispectral data, multi-temporal coverage, and cost-effectiveness, plays a significant role in change detection and habitat mapping. It a practical approach to collect data from diverse, inaccessible ecosystems and to study complex geographic terrain types. The amalgamation of GIS and remote sensing is successfully applied in monitoring and mapping of the coastal and marine ecosystem. Since 1972, Satellite imagery is available for most of the world, with the launch of LANDSAT by the USA. This treasure trove of information helps us to map and monitor the changes that happened to our coastal areas. The changes include the destruction of mangroves, land reclamation, shrinkage of lakes, estuaries, and other water bodies that are directly linked to the fisheries sector. Satellite imagery permits monitoring different features of the landscape and helps to quantify the rates of change and eventually detect significant land cover changes. GIS and remote sensing are extensively used to map and monitor the habitats namely seagrass/seaweed/coral reef.

Application of GIS in Marine fisheries management and conservation of marine resources: The GIS-based studies will give a clear picture of the Spatio-temporal distribution of fishes in the selected study area and help in identification of critical fishing grounds in terms of fishery and marine biodiversity (Dinesh, Thomas, and Rohit, 2014) [3]. The analysis of information collected in layers will help in identifying spawning period, spawning area, juvenile segregation, juvenile migration, *in situ* growth of different species, resident taxa of particular fishing ground, multi group assemblages, and the basis for the multi-group gatherings and their dependencies. Application of GIS in marine fisheries is being implemented as a project for the first time in India along Karnataka coast, where this study based on the database created on the trawl fisheries of the Karnataka coast (Shubhankar *et al.*, 2018) [1]. The other uses of GIS are for defining fish habitat and organizing and executing living marine resources (i.e., the dynamics of marine objects), tracking marine mammals and analyzing their hunting and migrant lines; which can assess the efficiency of marine protected areas, and answer to problems related to environmental ruins. (NOAA, 2017) [7]. Participatory GIS applications have been developed recently, which can be useful in the fisheries management sector. These application tries to collect and integrate local knowledge along with verified scientific data. In this type of application, marking specific locations or features is very much important based on a base map of the definite fishing grounds, and for that, a resource user is an utmost necessity.

Mapping and Geospatial Technique in Wetland: It is important to have an inventory of wetlands and their catchments in terms of conservation and management of wetland resources. Digital maps are potent tools to achieve this. Therefore, Maps are essential for monitoring and quantifying the change over time scale, and it helps in decision making. The technique used in the preparation of the map started with the ground survey. The Survey of India (SOI) topographical maps are the earliest correct maps of India, which shows various land use/cover classes, including wetlands. Remote sensing is recognized as an essential tool for making decisions, viewing, analyzing, and characterizing land, water, and atmospheric components. Space Applications Centre (ISRO), Ahmedabad, which has carried out the first scientific mapping of wetlands of India by using remote sensing data from Indian Remote Sensing satellites (IRS-Series) during 1992-93.

Role of GIS in the Wetland ecosystem: The wetland boundary should ideally include all open water, aquatic vegetation as the wetlands all these (eg, aquatic vegetation like submerged, floating, and emergent weeds) and satellite images must give a clear sign of the wetland extent. The presence of vegetation in wetlands provides necessary information about its trophic condition. By using optical remote sensing data, there is a possibility to delineate floating and emergent types of vegetation

Assam Remote Sensing Applications Centre, Guwahati (ARSAC): ARSAC is an autonomous Council which established in the year 1987 under ASTEC (Assam Science Technology and Environment Council). It has three main objectives, which are:

1. To develop remote sensing techniques and all the applications of all the methods for natural resources management in the State.
2. To provide consultancy facilities and training in remote sensing related fields, especially to the user agencies, by giving both visual as well as digital interpretation tools.
3. To help Govt. & Non-Govt. agencies in the preparation of their development plans with geometric accuracy based data and information through remote sensing techniques.

The wetland atlas of Assam:

The total number of the wetland is 5097, where 6081 (< 2.25 ha) are Small wetland. The total estimated wetland area is 764372 ha. Lake/Ponds, Waterlogged, Ox-bow lakes occupy 51257 ha, 47141 ha 14173 ha respectively (NWIA Assam, 2010).

Area estimates of wetlands in Assam

Sl.no	Wet code	Wetland category	Number of wetlands	Total wetland area	% of wetland area	Sl. No	Open water (area in ha)
						Post monsoon season	Pre-monsoon season
	1100	Inland wetlands- natural					
1	1101	Lakes /ponds	1175	51257	6.71	34408	14526
2	1102	Oxbowlakes/ cutoff meanders	873	14173	1.85	7721	5848
3	1103	High altitude wetlands	-	-			
4	1104	Riverine wetlands	139	4258	0.56	1669	942
5	1105	Waterlogged	2461	47141	6.17	33660	12630
6	1106	River/streams	213	637164	83.63	342197	353756
	1200	Inland wetlands-man made					
7	1201	Reservoir/barrages	2	2833	0.37	2185	1346
8	1202	Tanks/ponds	180	921	0.12	892	801
9	1203	Waterlogged	54	544	0.07	336	303
		Subtotal	5097	758291	99.20	423068	390152
		Wetland(<2.25ha) mainly tanks	6081	6081	0.80	-	-
Total			11178	764372	100.00	423068	390152

District wise Wetland distribution of Assam

Sl.no	District	Geographic area (sq. km)	Wetland area (ha)	% of total wetland area	% of district geographic area
1	Kokrajhar	3129	24833	3.25	7.94
2	Dhubri	2838	56538	7.40	19.92
3	Goalpara	1824	33221	4.35	18.21
4	Bongaigaon	2510	22149	2.90	8.82
5	Barpeta	3245	59038	7.72	18.19
6	Kamrup	4345	43655	5.71	10.05
7	Nalbari	2257	20140	2.63	8.92
8	Darrang	3481	48983	6.41	14.07
9	Marigaon	1704	28737	3.76	16.86
10	Nagaon	3831	35695	4.67	9.32

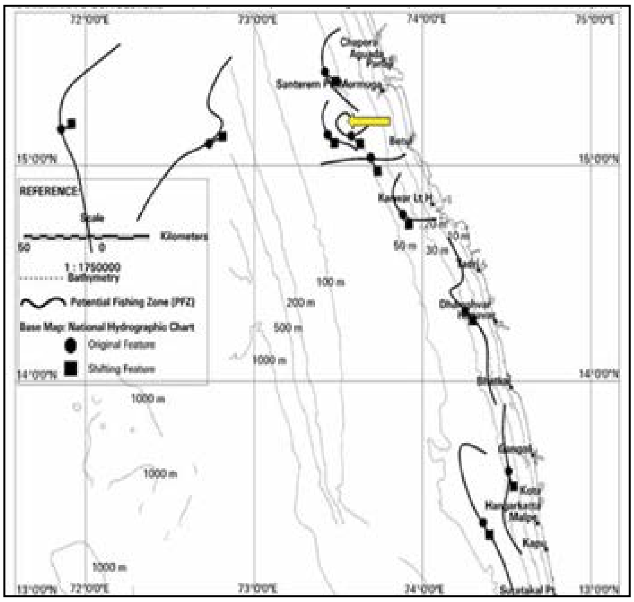
11	Sonitpur	5324	83427	10.91	15.67
12	Lakhimpur	2277	27307	3.57	11.99
13	Dhemaji	3237	33468	4.38	10.34
14	Tinsukia	3790	40626	5.31	10.72
15	Dibrugarh	3381	72461	9.48	21.43
16	Sibsagar	2668	12582	1.65	4.72
17	Jorhat	2851	45979	6.02	16.13
18	Golaghat	3502	43635	5.71	12.46
19	Karbi Anglong	10434	5810	0.76	0.56
20	North Cachar Hills	4888	6619	0.87	1.35
21	Cachar	3786	10419	1.36	2.75
22	Karimganj	1809	6450	0.84	3.57
23	Hailakandi	1327	2600	0.34	1.96
Total		78438	764372	100.00	9.74

The maximum area of wetland present in Sonitpur District. The total wetland area in the district is 83427 ha that includes 980 small wetlands (<2.25 ha). River/stream occupies 94.52% of wetlands. The other major wetland type is Waterlogged - natural (2.22%) and Ox-bow lakes (1.04%).

Hailakandi has the lowest area of wetland (2600 ha), that includes 30 small wetlands (<2.25 ha). The major wetland type is River/stream (66.27%). Total 19 Lake/pond covering 575 ha area (22.12%). The other major wetland type is Waterlogged-natural (10.46%).

Some critical aspects of PFZ:

- When PFZ is in the form of a line, then fishing at the Center of the line will give the maximum catch.
- If the PFZ to as a curve, then fishing inside the curved area will yield a maximum catch. (Fig:1)
- If two or more PFZ is there close to each other, than fishing in between those gives a better catch. (Fig:2)



Benefits of GIS

1. GIS provides a vast range of tools that allow for accuracy of output and thoroughness of decision making.
2. To create a new map it is a simple task to update them, to change or to merge them with other maps, once maps have been established in a digital format.
3. The range of possible graphic displays is almost infinite, which allows maps to be customized to match situations and individuals, and for visualization experiments to take place.

4. The GIS contains the prerequisites for modelling scenarios concerning the research aspect and operational resource management tasks.
5. The GIS allows for the smooth and immediate integration of other large data sets.
6. The GIS allows for the display of spatially related data in a way that is easily understandable and comprehensible to most people.
7. The use of GIS significantly improves the speed of working in all map producing operations thus human productivity.
8. The GIS allows for a regular flow of spatially related information in a standardized arrangement. It might be for a particular time, where all maps are created together, or sometimes a different version of the same map can be uploaded.
9. The GIS allows for the production of one-off maps of a high quality, which would otherwise be non-cost effective.

Disadvantages of the GIS

1. The input sources to a GIS may be of a varying standard. This means that a certain degree of error propagation will be inevitable, and the extent of this is difficult to measure.
2. GIS implementation will undoubtedly have an impact on the department, such that organizational changes will be compulsory. There could well be inevitable losses in this process.
3. The cost of data inputs can be high, either in terms of purchasing existing digital data or in maintaining and setting up data gathering systems. These costs may be unpredictable at an early stage. So the actual value of utilizing a GIS is challenging to found.
4. The means and degree of access to data sources will be variable. The legal position concerning this is sometimes poorly determined or unnecessarily restrictive. There are copyright problems in making newly created data available.

Conclusion

By delivering goods and services through proper route planning, GIS tools can save billions of dollars annually. GIS regularly helps in the day-to-day management of many natural and human-made resources, which includes sewer, water, power, and transportation networks. Applications of GIS in marine and coastal ecosystem study is an emerging field today. The marine geographical interpretation using GIS became a vital tool in the field of marine policy making, planning, and conservation. The critical role that GIS plays to the cooperation of organizations in various international agreements for the management and the use of the marine areas include maritime transport, fisheries, recreation, disposal of waste, conservation. For the purpose of resource availability analysis, though numerous technologies are being conceived still GIS is the most propitious one. GIS helps to access food fishery potential, judge the environmental health of river and lake basins and allocate resources between the management of fisheries and the development of aquaculture. It also helps us to identify the source, location, and extent of adverse environmental impacts. GIS enables us to devise practical plans for monitoring, managing, and mitigating environmental damage. Analysis of satellite data helps in assessing the productivity of resources, whereas GIS may help in the comprehensive development plan for fisheries. To apply GIS tools in the fishery sector, the central government should take a collaborative program, the state government through their remote sensing centers, universities. National Remote Sensing Agency and Space Application Centre, Planning Commission, should come forward to approve and provide funds for such a project. Several studies have been done in the marine sector using GIS, while studies in the Inland sector have been very minimal. Hence, more focus on the use of GIS in the Inland fisheries sector should also be taken to tap the maximum production potential.

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