PLANNING AND MANAGEMENT OF THE COASTAL AQUACULTURE THROUGH GIS TECHNIQUES

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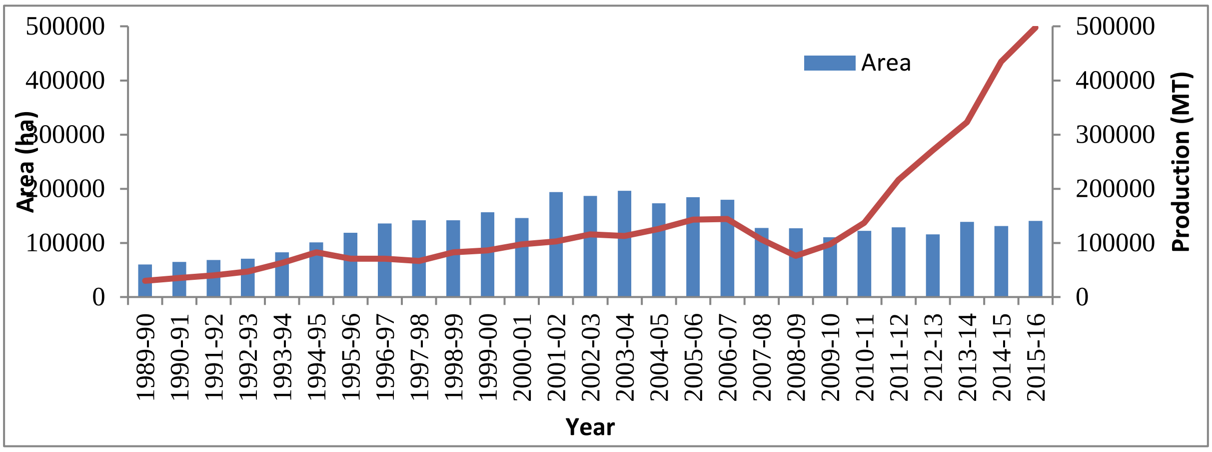
Abstract
Aquaculture contributed 80.03 million tonnes of food fish, remains as one of the fast-growing sectors of the world. The unregulated fast growth has raised many environmental issues such as conversion of mangroves and agricultural lands to aquaculture farms and salinization of land and water resources. Out of 1.2 million ha of area available for aquaculture in India, the present level of utilization of 14 % indicate the huge scope for expansion, but the issues raised due to unplanned growth has questioned the sustainability of the sector, necessitates the need for planning the aquaculture development. GIS techniques such as union analysis for impact assessment, weighted overlay analysis for site selection, TIN and spatial analytical tools for climate change impact on aquaculture resources have been used for the decision making. Multiple spatial criteria such as land resources availability, water quality, soil characteristics, water availability and environmental regulations have been used in planning for aquaculture. The study carried out by CIBA in the coastal districts using GIS techniques for aquaculture expansion has paved the way for state level planning in Maharashtra and Tamil Nadu. Apart from site selection, GIS has been used to explore the impact of aquaculture on land use change in India's coastal wetlands, which demonstrated the mangrove areas have undergone intensive change due to gain and loss and the overall extent of mangrove has increased by 13 %. Studies carried on climate change impact on coastal resources indicated the potential threat faced by aquaculture in future. Overall, GIS has become indispensable tool in planning, monitoring and managing the development of aquaculture with sustainability.

1. Introduction

The demand for aquatic foods is expected to increase many folds in the decades to come due to growing global population and increasing health consciousness on the positive effect of fish on human health. There are several forecasts on demand for aquatic foods and it is expected that it will be 183 million tonnes by 2030. As the capture fishery production is stagnating at around 90 million tonnes, aquaculture is seen as the only alternative to bridge the widening gap in demand and supply (FAO, 2018). Globally, landings from worldwide aquaculture has increased 10-15 % per year in the last two decades and this growth was due to the combined effects of scientific farming, availability of infrastructure facilities, changing consumer preferences and export market potential to developed countries. Shrimp farming is relatively new and its introduction on a commercial scale can be traced to the early seventies. Despite the recent introduction, one third of the world shrimp production is from farmed shrimp. According to FAO, aquaculture contributes 80.03 million tonnes of food fish to the world, at an annual growth rate of 5.8 % between 2001 and 2016.

India's coastal line stretches to 8118 Km, distributed in nine coastal states and 4 union territories, with 14 major river systems which has led to formation of wide network of creeks and estuaries in the coastal areas of the country facilitating 1.2 million ha potential for coastal aquaculture. In India, aquaculture has changed from a traditional to a commercial activity in the last three decades and shrimp farming was synonymous with monoculture of tiger shrimp, *P. monodon* till 2009 with a per capita productivity of one ton/ha, then *P.vannamei* was grown with the average production of 7-9 T/ha (CAA, 2014). The area and production increase due to aquaculture is given in figure 1. Introduction of *P. vannamei* in 2009, led to the recovery of the sector with the production levels reaching 497622 MT (MPEDA, 2018), generates 33000 crores export foreign revenue.



. Fig.1 Year wise area and production of shrimp aquaculture.

2. Environmental issues due to unplanned aquaculture

The unplanned proliferation of aquaculture farms for maximizing short-term returns without addressing sustainability has created many concerns worldwide, particularly in the Asian countries which needs to be addressed logically with advanced spatial tools. Comprehensive planning for the aquaculture is still uncommon and the facts that many farms are abandoned or are suffering significant disease problems demonstrate the need for such improvement in planning.

Shrimp aquaculture has developed initially without any proper comprehensive spatial planning and faced sudden collapse of the sector due to massive disease outbreak in many countries. Shrimp pond disuse has become common in disease hit areas, but there was not much effort made for the reuse. Mangroves are highly productive ecosystems with great ecological importance in cyclone/Tsunami protection, breeding ground for many shellfishes and finfishes, shoreline stabilization, preventing coastal erosion, sediment and nutrient retention, storm flood and flow control, carbon sequestration and maintaining coastal water quality. But the rapid development of shrimp aquaculture was considered as the major man made changes contributing to loss of mangroves. In Southeast Asia, which possesses 35% of the mangrove forests in the world the highest rates of mangrove losses were recorded in the last 30 years, reaching as much as 70-80% in Vietnam and the Philippines. The growth of shrimp farming from other productive land types, particularly from agricultural lands and mangroves led to the litigation at international and national level. Salinization of freshwater aquifers have been reported in Taiwan, Philippines and Thailand as a result of ground water abstraction for intensive shrimp culture, seawater intrusion due to excessive pumping into inland water. To develop aquaculture with long term sustainability and social acceptance, planning is essential with incorporating ecologically important ecosystems presence and other coastal resource use in an environmentally-integrated mode. In addition, aquaculture development is faced with several challenges relates to climate change due to global warming with increasing extreme events such as floods, cyclones, drought, tsunami and vulnerable to climate change as it depends on land and water resources completely. The emerging scenario necessitates the ICAR - Central Institute of Brackishwater Aquaculture, Government of India to plan for the development of sustainable aquaculture.

3. GIS for Aquaculture development and management

Globally, GIS has been extensively used for the management of coastal resources. The capability to perform several functions such as spatial data collection, storage, manipulation, analysis and geographical representation, distinguishes GIS from other information systems such as Computer Aided Design (CAD) and Data Base Management System (DBMS). GIS, as an analysis tool discerns relative location by defining the spatial relationships among all map elements. GIS is mostly used for optimizing site selection, impact assessment, monitoring development either in combination with remote sensing or alone in aquaculture. The vast brackishwater resources available along the east (0.65 million ha) and west coast (0.55 million ha) of India and their present level of utilization of 14 % indicate the huge scope for aquaculture expansion. But this assessment will vary in the present context due to Coastal Aquaculture Authority (CAA) act requirement of environmental restrictions and compulsory buffer zone between land classes for the development of aquaculture. Most of the problems faced by the shrimp industry in India in the recent past could have been avoided if planning and site selection were done properly.

3.1 Multi criteria decision support tool for site selection

Planning for aquaculture not only depends on the availability of suitable resource parameters but also through understanding of the environment to know what exists in nearby areas and any impact it can have on them. Proper site selection for setting up aquaculture farms are very important management measures, which can mitigate negative impacts. The site selection needs multiple criteria such as land availability adhering to environmental regulations, suitable soil texture to prevent seepage in adjacent lands, appropriate soil and water characteristics and transport and drainage network availability and proximity in the proposed.

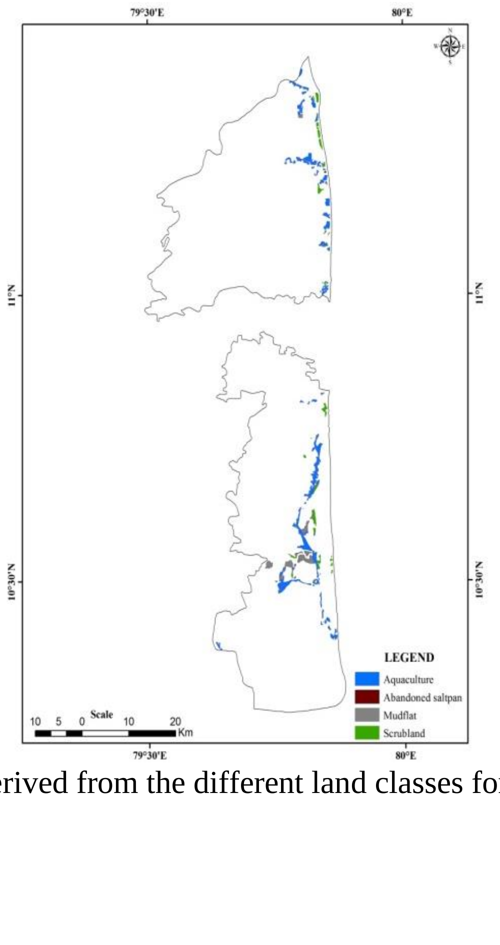


Fig.2 Suitable sites derived from the different land classes for aquaculture

GIS can handle and spatially relate the multifaceted data to derive the decision for aquaculture site selection and rank the sites based on the site suitability index. As an example, fig 2 indicates the output after the site suitability analysis for coastal aquaculture based on site specific characteristics and environmental regulations

3.2 Impact of aquaculture development on mangroves

Major environmental issues have been raised over the development of aquaculture such as the conversion of important coastal ecosystems like mangroves and agricultural lands to aquaculture farms. The loss of mangrove forest area due to shrimp farming has been widely recognized as a main environmental issue. This deforestation is still taking place in different forms, even though the importance of mangroves is known. These issues are the major constraints and threats for the future development of the aquaculture, will lead to depletion of ecologically highly important resources.

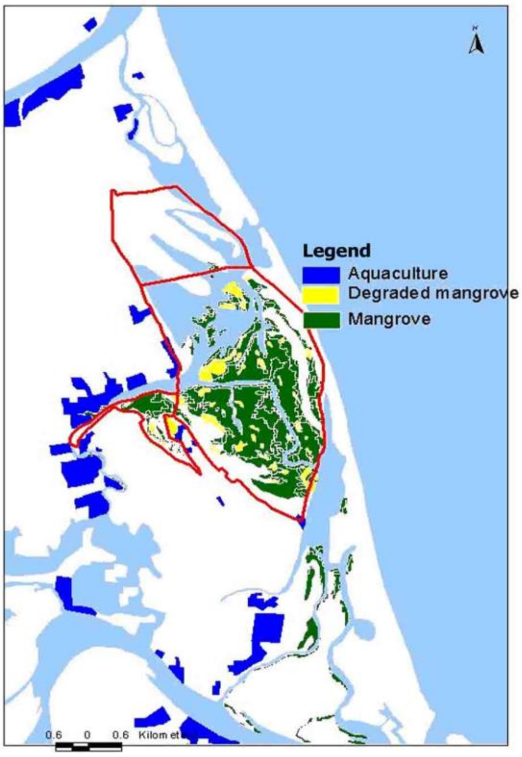


Fig.3 Mangroves and aquaculture at Pichavaram wetland

RS together with GIS can be a platform to assess EIA of aquaculture with multi temporal data analysis to assess the periodical, quantifiable changes on coastal environment due to aquaculture. Fig.3 indicates the aquaculture development near Vellar Coleroon wetland.

3.3 Quantification of abandoned shrimp farms

Disease problems and environmental regulations made the vast areas of shrimp farms unused after short term use. The shrimp ponds in disuse pose major danger to sustainability of costal resource use as the scenario of abandoned shrimp farms in Southeast Asian countries are in alarming trend. RS coupled with GIS have the capability to provide detailed information on abandoned farms with its erstwhile land use for larger areas. Study carried out by CIBA indicated the spatial spread of abandoned shrimp farms and its earlier land use (Fig. 4) in Andhra Pradesh.

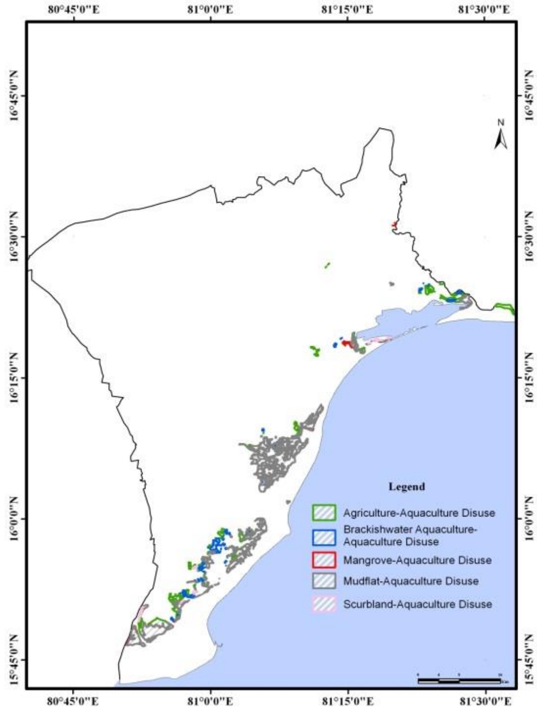


Fig.4 Assessment of abandoned shrimp farms and its earlier land use at the coastal Andhra Pradesh.

3.4 Assessment of climate change vulnerability on aquaculture resources

The changing climate variability of extreme events, heavy rain in shorter duration, increasing flood and cyclone often damage the facilities and crop in shrimp farms. In addition, projected increase in sea level rise expected to bring more areas under water.

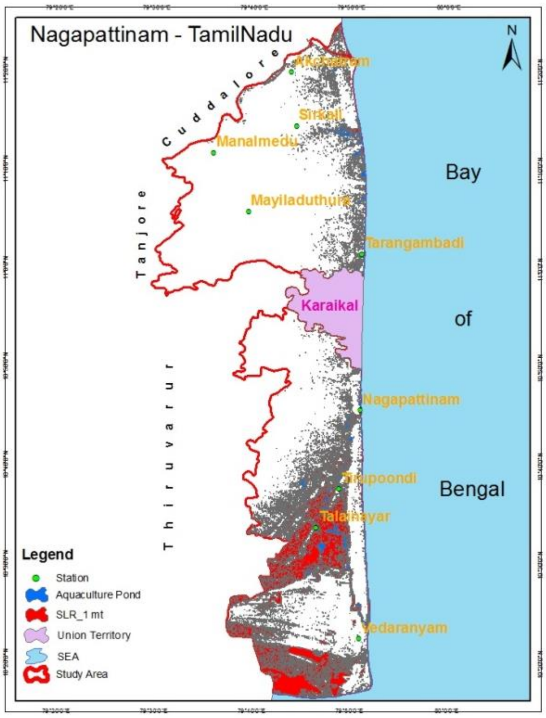


Fig. 5 Inundated zones projected for SLR at Nagai district of Tamil Nadu

The elevation above mean sea level, high intensity rainfall zones, frequency and intensity of floods, water flow in source water bodies, monsoon pattern, changing water salinity during rainfall, topography of the site, geomorphology, slope, shoreline changes and wave height are some of the factors need to be involved in the site selection. GIS can help to spatially integrate and interpolate the data to assess the calculation of changes and identify the vulnerable coastal area, which demands the special resilient management measures for the successful aquaculture. Case studies of selected low lying regions indicated the adverse potential impact of SLR and storm surge in Nagapattinam district of Tamil Nadu (Fig.5), Alappuzha in Kerala, South 24 paragons, Sunderban mangroves in Westbengal, projected inundation to the tune of 17-35 % of the present area at 50 cm SLR with storm surge. Small changes along the shoreline can reach far inland due to plain topography.

Conclusion

GIS continues to evolve at a rapid pace in aquaculture monitoring, development and management as advances are being made with regard to ease of use, manipulation of large datasets, and interpretability of datasets. The most significant development is an increasing trend towards the use of GIS is the creation and management of large decision support system, that can be effectively applied in the management of aquaculture. With the present trend of increasing infrastructure capabilities, developing countries like India can develop a sustainable aquaculture through GIS.

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