Chapter 2

REVIEW OF LITERATURE

This chapter involves a review of literature on major fields related to the present study. It includes the development of shrimp culture in coastal areas and their socio-economic as well as environmental impact using Remote Sensing and Geographic Information System (RS & GIS) techniques.

2.1 Shrimp culture development

During last three decades, many countries of Eastern and Western Hemisphere have experienced high economic growth due to the culture of shrimp in large extent in the coastal areas. The two most developed shrimp culture areas of the world are – Asia and Latin America. In Asia, mainly South East Asia is involved in shrimp culture, whereas more active shrimp farming is noticed in Northern part of South America and Middle America. About 75% shrimp production comes from Asian countries. China and Thailand are two main shrimp production country closely followed by India, Vietnam and Indonesia. Rest of 25% is produced in the western hemisphere mainly in South American countries. Nowadays India moves to the leading exporter country in international shrimp trade. According to the year of 2016, India is one of the top five shrimp exporters where the other countries are Vietnam, Indonesia, Thailand and China. In the year 2016 total exported shrimp was 4,38,500 MT in global market only from India whereas Vietnam was 4,25,000 MT, Indonesia was 220,000 MT. On the other hand production of China was also increased up to 7% which was in total 205,300 MT. The EU and Japan were the India's top export market (FAO, 2018).

The rapid growth of shrimp production is successfully achieved due to many reasons. They are mainly is in the following:

1. Diversion of traditional shrimp culture in scientific shrimp farming.
2. Technical evolution of Vannamei shrimp culture from Tigher shrimp culture.
3. Huge brackish water source favourable for shrimp farming. The south-east coastline of the country has the highest availability of brackish water resources.

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4. Extensive to intensive shrimp culture development technology.
5. High profitability and high demand of foreign market.
6. Loss or marginal profit of the rice cultivation.

2.1.1 Shrimp culture development in India

Shrimp culture in India started a few decades ago. In the year of 1980s, it has been started with a very small scale in south-east India. After 1990 it has been rapidly grown in the coastal areas of Andhra Pradesh, Tamil Nadu and Orissa. As a result, highest concentration of shrimp farming was seen in those areas before few years back. Goa, Maharashtra also have some activity in shrimp farming, but the culture area is much lesser compared to the east coast (Yadava, 2002). Commercial shrimp culture is mostly spreading on the coastal regions of Andhra Pradesh, West Bengal, Tamil Nadu and Odisha. Brackish water shrimp farming is mainly done in huge level for export. Among the coastal states, West Bengal and Andhra Pradesh were the largest producers of P. monodon and P. vannamei shrimp respectively in the country during the year 2014-2015. Recently P. vannamei is the most cultured shrimp in terms of production and productivity in India. The commercial farming of Tiger shrimp decreased gradually due to high virus infection; on the other hand, Vennamei shrimp started increasing significantly from the year 2010-11 (Laxmappa, 2016). Details of shrimp culture production statistics in India is shown in Figure 2.1

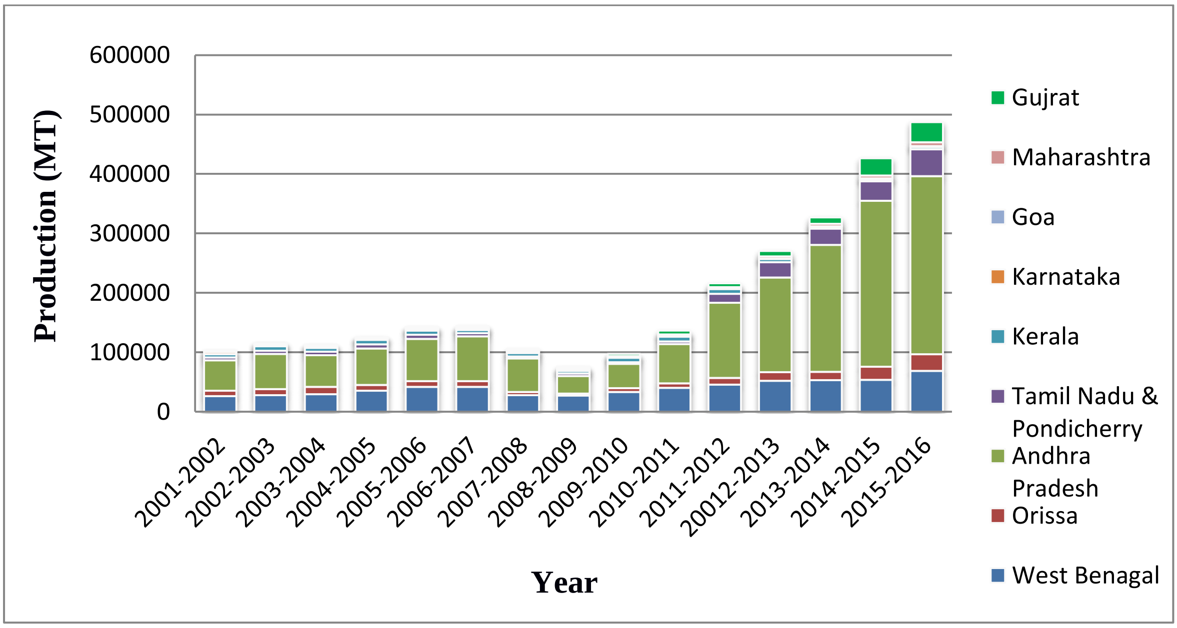

Figure 2.1 Shrimp culture production statistics in India (Source: MPEDA)

2.2 Impacts of shrimp culture

From the last three decades, due to the high demand for shrimps in developed countries like North America, Europe and Japan large-scale shrimp farming has grown. For the significant of the global economy, the earning from coastal shrimp culture affect a lot. Still, its adverse effects on biophysical environment and society have also attracted colossal attention which needed to be considered with utmost care. All significant positive and negative outcome of shrimp culture are elaborated in this module.

2.2.1 Positive impacts

Shrimp culture generates great revenues and huge employment opportunities with a contributed to the economic condition of the country and upgraded the living standards of the local people by giving them a better chance to work with good pay. Hence the socio-economic improvement is considered as the most positive impact of shrimp farming.

Significant positive benefits of shrimp culture are in the following:

1. Support to the national income through high export earnings.
2. Productive use of coastal saline soil.
3. Opportunity for the coastal villagers to improve their financial condition.
4. The destructive pressure on coastal fisheries, forests and other natural resources will be reduced.
5. There will be a huge employment opportunity for local people. Local people got engaged as human resource in ancillary activities like technician, processing, marketing, production, transporting and selling of feed, seed etc.

Shrimp farming is primarily practiced in coastal brackish water. Because of shrimp culture in the area, high-value economic activities also take place, and it also opens up the opportunity for poor villagers of the coastal zone. People got involved in ancillary businesses and the farmers who are earning minimal amount get a chance to improve their lifestyle by shifting their work related to shrimp farming. According to the global estimation, it has been found that shrimp farmers can earn 1.5-3 times as compared to other jobs (World Bank et al., 2002). According to another report of 1996 about Mexico, it was seen that the lowest paid job of a shrimp farm was 1.22 times more than the average worker's salary of the country (Lewis et al., 2003). According to Barraclough and Finger-Stich (1996), when a farmer shifts his work from growing rice to shrimp farming he could increase his income by ten times. Kumaran et al. (2003) concluded at similar figures for shrimp farming in East Godavari district of Andra Pradesh.

2.2.2 Negative impacts

No doubt that the economic growth due to shrimp farming is evident, but it raises some environmental issue like destruction of natural habitats, weakening of natural resources and pollution. Despite of remarkable success in the economic sector, shrimp farming also raised many problems such as large-scale moralities because of virus infection, negative impacts on the environment, trade restrictions, too much of production, sector competition and over capitalization (FAO, 2002). The environmental impacts due to shrimp farming are because of consumption of resources, (soil, water, seed and feed etc.), the subsequent release of wastes into the environment and transformation of resources into product value by society. Release of toxic chemicals, disease transfer, parasites and the introduction of genetic and exotic material into the environment are considered as the direct impacts. The indirect environmental impact can be the loss of natural habitats and dis-balanced space and food chain (Primavera, 1998).

Due to both socio-economic and environmental issues, the opposition to shrimp farming has stemmed. In case of socio-economic issue, this includes effect on traditional agriculture, land alteration; coastal communities' displacement from access to public land, grazing, financial risk, loss of land security etc. several other environmental impact of shrimp cultural include large-scale degradation of coastal wetland, deforestation, embankment collapsing, salinization of surface water and agriculture land, pond effluents pollution of coastal water, wild larvae loss and corresponding resource system generated goods and services loss etc. are also the environmental impacts of shrimp culture. Overcrowding of ponds and poor development are severely affecting the surrounding environment and are also initiating a self-pollution process that leads to abandonment of vast farming areas. Shrimp farmer of Peddaputtapadi village in Krisna district of Andra Pradesh abandoned shrimp culture in 1998. The primary reason for the decrease of shrimp production is abandoning of shrimp culture after environmental degradation of pond (Rao, 2006). The sustainability issue of shrimp culture is elaborated in the next section.

2.2.2.1 Conversion of agricultural land

High profit of shrimp farming motivates the villagers eagerly to do more shrimp farming. As a result, coastal villagers convert their agricultural land to shrimp ponds. Kumaran et al. (2003) have noticed the great interest to convert the agricultural land to shrimp farms among rice farmers of East Godavari district of Andra Pradesh for shrimp farming due to high profit. Many shrimp farms are established over the agriculture land which was earlier used for rice cultivation. According to Hein (2000) shrimp farming highly effects the production of rice due to seepage and leakage of saline water and the different pollutants from the shrimp ponds. Saline water is essential for shrimp farming. In the embankment of the coastal area farmers frequently cut the coastal embankment to supply the saline water through man made canal for shrimp farming. As a result, rice fields are inundated by the saline water and their rice production gets badly damaged. Due to self-pollution, infestation and other collateral affect the life-span of shrimp ponds are limited to 5-10 years under intensive system shrimp culture (Primavera, 1997). In that case, shrimp farmers abandon the shrimp farms and move to other new pastures in a pattern which is often referred to as 'rape and run' (Csavas, 1994). In Kerala, the traditional shrimp farming is done in the agriculture fields (paddy fields) in rotation basis with combination of paddy crops. When it is not possible to do in rotation basis due to drop down of rice production, the agriculture land is then permanently converted to shrimp farming zone. Because of the high rising demand of coastal land due to shrimp farming, the cost of land is getting high. The local farmers sell their property because of their greediness of their costly land (Mukul, 1994). The tradition to shrimp farms is irreversible, that means once shrimp farming is done in some areas/land, the land becomes sterile and it would again not be possible for any other agricultural activities. Abandonment of shrimp ponds in large scale is reported from top shrimp producing countries of the world (Lassen, 1997). The data which indicates the estimated area for abandoned shrimp farms worldwide is as high as 1,147,300 hectares in 1994, whereas 847,000 hectare was in Asia. According to Clay, (1996) total 620 ha of rice field area were transformed into shrimp farming area. Again due to contamination with salt water, another area of 344 ha was badly affected. In the central areas of Thailand, the release of saline shrimp pond water has caused salinization in the nearby rice fields (approximately 45000 ha) and shrimp farms (Briggs, 1994). FAO (2000) reported that inland shrimp farming was banned in Thailand since 1999 due to salinization, which causes the huge destruction of agriculture lands. In between 1989 to 1996, almost 60% of shrimp culture area in Thailand has been left for no further use because of excessively increasing salinity in the soil (Hossain and Lin, 2001). It affects the land in the long term basis because of the release of a large volume of sewage water, though the effluents create comparatively low pollution than industrial waste water, even lower than domestic waste water (Machintosh and Phillips, 1992).

2.2.2.2 Deforestation

Mangroves are very precious coastal resource of our country. These coastal forests (mangroves) are beneficial for the breeding, swapping of economically valuable fishes. Mangroves also act as coastal stabilizer and coastal belt for shelter. From the erosion and cyclonic destruction, these mangrove forests due to its formation are capable of saving coast areas. The financial and ecological problems of the shrimp farming are largely related to deforestation mainly destruction of mangrove tree and saltmarsh plants. Almost in aquaculture systems, mangroves are cut to create small dyke by the operator along with water retain sluice gates. Planted mangroves are exceptions.

According to Philips (1995) in South East Asian coastal zone, huge mangroves area, particularly during 1980s and early 1990s, are destroyed to make shrimp ponds, and it has harmfully affected coastal paddy fields. According to data collected by Rosenberry (1998), approximately 1 to 1.5 million hector lowland coastal areas are changed to shrimp farms in the countries of China, Thailand, Mexico, India, Indonesia, Philippines, Malaysia, Nicaragua, Honduras, Panama and Ecuador. In 1995, the National Environmental Engineering Research Institute (NEERI) studied the socio-economic impacts of development of aquaculture industry in India. The study reported that the economic losses due to the conversion of mangroves and agriculture lands for aquaculture in Andra Pradesh is Rs 803 crores and in Tamil Nadu is Rs 140 crores and converted area is correspondingly 9500 ha and 1600 ha. Ashton (2008) discussed the major issues involved in shrimp farming which include degradation of ecological functions, socio-economic conditions, loss of mangrove ecosystem, use of chemicals and medicines, introduction of new diseases, changes in hydrology, loss of livelihood and social conflicts are the noticeable adverse effects of shrimp farming.

In the year of 1999 Rivera-Monroy et al. estimated that almost 0.04 – 0.12 ha of mangrove forest is to be cleared to remove the dissolved inorganic nitrogen load from effluents produced by 1 ha semi-intensive shrimp pond. Turner (1977) calculated that for each hector of mangrove changed to others uses, yearly culture of shrimp and fish from wild resources decrease by 767 kg. Mangrove wetlands are useful as filters of pond effluents before releasing into adjacent water bodies. In a regional perspcetive, the ratios of areas of the mangrove forest and shrimp pond is proposed to maintain the proper balance between the areas dedicated to shrimp farming and mangrove ecosystem. The waste of shrimp farms and the chemicals used in shrimp farming badly affects the ecosystem of mangrove forests which results in decrease of mangrove resources and services.

2.2.2.3 Unscientific use of chemicals and drugs

Shrimp farming business has really good money earning way if the farms are capable of maintaining its crowded shrimp ponds. Hence to support the higher productivity of farms, farmers use artificial feed, chemicals, antibiotics etc. Due to unscientific continuous use of these chemicals and drugs the waste water of shrimp farm becomes highly polluted than the normal and it become very vulnerable when the contaminated waste water is released to nearby river/stream/canal and sea. From the old records, it is seen that antibiotics are closely related to intensive shrimp culture, both in grow out ponds and hatchery (Philips et al., 1993).

Adverse effect on the environment and human health is seen because of unscientific use of antibiotics in shrimp farming. This use of antibiotics develops resistance among the pathogens. In a sample testing in Thailand domestic market in 1990-1991, it was found that antibiotics such as oxytetracycline and oxolinic acid were present above the permissible level in Tiger Shrimp (Saitanu et al., 1994).

2.2.2.4 Water and soil quality deterioration

The effluents of shrimp ponds profoundly affect the water and soil quality. The environmental degradation of the waterbodies by discharge of the pond effluent is one other activity. The neighbouring farms often use the receiving water which in turn is the cause of various water-borne diseases. Due to the intensive practice of shrimp farming in Southeast Asia the pollution level in the coastal areas has increased drastically. The pollution level due to the effluents is so badly increasing that now if it is not sincerely taken care of the matter of intensive shrimp farming in Asia can completely dis-balance the ecological conditions of the coastal areas of this continent. Both the receiving water and pond water are extremely polluted for the effluents. These effluents help to enrich the nutrients and minerals, and as a result, the plants and algae experience excessive growth which in turn affects the coastal environment (Phillips et al., 1993). One of the most common environmental impacts of intensive shrimp farming is brackish water seepage from the shrimp ponds into ground water supplies. To reduce brackish water salinity level shrimp farmers pump out large volume of underground water which in turn lowers the ground water level, making aquifers empty and increase salinity in the adjacent land and waterways. The pumped out waste water of shrimp farms go back to the environment and also causes pollution and increase salinity in local lakes and waterways (Pillay, 2007). Patil and Krishnan, (1998) have described that salt water seepage from the shrimp ponds has increased the salinity of underground aquifers.

Grant and Briggs (1998) discussed that soil quality should be examined frequently in coastal areas surrounding shrimp farms because of organisms that can get affected due to antibiotics and other medicinal chemicals use to the feed. The redox potential of soil (Eh) shows an increased reducing condition from intake (-90 mV) through discharge point at harvest time (-143 mV). With the indication of rise in organic matter, the organic carbon content shows a progressive increase. According to Joseph et al., 2003, during the harvest time organic carbon content at intake point is 0.21% and at discharge point is 0.80%.

2.2.2.5 Socio-economic impacts

Environmental and social degradation is pointed out to be the root which causes many conflicts that stem due to the growth of shrimp culture. This growth of shrimp culture has brought some negative effect on society. The society, particularly the poor, has to bear the adverse effects of the expansion of the shrimp industry. Most adverse effect of shrimp farming includes the change in land use pattern, declination of quantity and quality of the environmental resources, dis-balancing the livelihood, environment and food security.

In India, in the last few years, 80,000 ha of land are transformed into shrimp farming sites. On the other side, freshwater fishing families are suffering due to pollution created from shrimp culture which is polluting the water bodies nearby. The new and modern farms which have adopted scientific technologies are capital intensive. They are no more labour intensive (ADB/Infofish, 1991); Local people got job in a ground level, where has no requirement of skill. With the commencement of shrimp farming, the competition for natural resources between the customary users and the new users (shrimp farmers) increased. In this competition, the shrimp farmers used to dominate because of their money power and contacts with political and bureaucratic top brass. Development of shrimp culture opened up a new option of profitable use of land. But the enormous amount of investment and the high risk involved in shrimp farming tempted small and marginal farmers in the area to sell their land to outside entrepreneurs. These people are ready to pay an excellent price for the paddy fields. Conversion of paddy fields into shrimp farms has affected paddy production and retrenched farmers and workers from paddy cultivation. Farmers and agricultural workers are deprived of their traditional means of livelihood, forcing them to seek employment in the wage labour market in rural and urban areas (Ito, 2002).

2.2.2.6 Food security

Shrimp is a high-value commodity with massive demand in the foreign market. It is a part of the menu of luxurious consumption by the elite. Price of shrimp in domestic and international markets is so high that it is not possible for the poor people to effort it. Production of shrimp in farms makes little contribution to food requirements in the domestic market and local food security; even though the significant shrimp producers are the backward economic region in Asia. Most of the products are exported to rich countries like USA, Japan, countries in European Union etc. All mono-crop (tiger shrimp) farms sell all their production to export firms or their agents. In the case of traditional farms also, the high-value tiger and white shrimps are sold to agents of export firms, while low-value other shrimps and finfish are sold in local markets.

According to Parthasarathy (1994) shrimp is produced at a very high opportunity cost in terms of production lost in agriculture, small fishery, animal husbandry, poultry etc., all of which catered to the food security of local population. In other words, high profit and foreign exchange earned from the production of shrimp farming is at the cost of food security of most vulnerable sections of the society. Expansion of the shrimp industry displacing paddy fields is described as "prawn revolution at the cost of [the] rice bowl". It is argued that shrimp exports are underpriced because shrimp entrepreneurs rarely include the social cost of shrimp production in the price of shrimp. The market value of shrimp doesn't reflect its 'true price', because it is based on private cost of shrimp farmers and ignores costs in terms of destruction of coastal natural resources. It is always a controversy that the countries which are doing shrimp aquaculture are losing more than they are gaining from the culture. Food storage is not properly alleviated. Conversely, it is creating more problems for the future of poor rural communities (Mulekom et al., 2006). The expansion of shrimp production in backward economic zone is intended to serve the tastes of the luxurious consumption abroad, leaving the domestic poor destined to starve.

2.2.3 Impact assessment

For impact identification and assessment Questionnaire Checklist and Leopold Matrix are very popular scientific methods. Questionnaire Checklist is the simplest method of assessment which involves a series of questions for gathering some important information for a research. The concept was invented by Statistical Society of London in 1838 and has come out as a very successful method of assessment. It is an easy way to interact with the locals who are secondary source of information of a particular study area. A Questionnaire Checklist should involve some specific content including some common impacts and risks. It is really very important to make a questionnaire in a very simple and comprehensible way so that maximum people can easily understand the concept and answer properly. A checklist helps to find out those areas which require more detailed assessment. In some cases, checklist itself represents the impact analysis.
There are two main factors available for environmental impact analysis. First is the "magnitude" of impact on a specific sector and other is the "importance". "Magnitude" is the sense of degree or scale and the "importance" is the significance of proposed action

on the specific importance of impact. Both "magnitude" and "importance" can be analyzed together with the help of Leopold Matrix and this method is very convenient for environment impact assessment. The Leopold Matrix has a significant advantage over the other impact assessment methods due to its matrix used as a checklist or reminder (Leopold et al., 1971). The scale of importance in the Leopold Matrix ranges from 1 to 10, where the importance increases with the increasing value with 1 being least important and 10 being the most important. Further plus (+) or minus (-) signs can be used to show the impact being beneficial or adverse.

2.3 Sustainable development

In the context of the development of shrimp culture, it seems really necessary to take care of the factors which are directly and indirectly affecting the sustainability of the environmental conditions. As a result of rapid increase of waterbodies across the world, there has been a lot of interest among international technical support organizations and national level government agencies in the country, where fish culture is still in its infancy, and that has raised significance concerns about the stability of the industries in the country that have been established. Aquaculture sustainable development can help to prevent or to control water pollution because it relies on right quality water resources. For sustainable land use, it is necessary to maintain the resources which have the potential of productivity and also required to check the land degradation condition. Not just soil refers to land but all the combination of resources which provide basis for the use which are terrain, water, soil and vegetation (World Bank, 1995). When discussion is done about sustainable management of a land, it is considered that it would enhance the financial performance of the land and would also maintain the environmental conditions of the surroundings preserving the cultural aspect of landscapes.

Globally shrimp culture is done mostly in the coastal areas and in the mangroves. Due to uprising of economic benefit, the coastal ecosystems, as well as the marine ecosystem, are very important. These must be used in the most efficiently so that the individuals and the society both can avail its benefit. Coastal ecosystem is mostly able to sustain more than one activity. Hence integrated planning and management in coastal areas would be very required to optimize the economic and social benefit.

The developmental activities in the shrimp farming areas are required to establish a sustainable development of shrimp culture, conservation of coastal environment, and balanced use of natural resources. To maintain the priority of those objectives, the Government of India in the year 1991 declared these zones as the Coastal Regulation Zone (CRZ). As per CRZ, there are some restrictions following which no one can set up or expand existing industry in a particular zone. The diversity of different coastal states is not distinguished by initial notification. Till the year 1996, for that reason, it was not under focus or purely ignored and then the Supreme Court of India made judgment in favour of coastal aquaculture. Later on in modern form, coastal aquaculture is restricted within Coastal Regulation Zone (Kumar, 2000)

The most important step for scientifically sustainable development of shrimp farming is to select a suitable site with a better management of the culture. Proper planning and monitoring are required for sustainable land use management. By understanding the importance of site selection in the development of sustainable shrimp culture planning of the land use has been done carefully to manage the coastal aquaculture areas. Shrimp culture planning is mostly applied focusing on management technique where zoning of coastal aquaculture is done to achieve improved sectorial plan. If considered all land use possibilities, it has much wider goal (GESAMP, 2000).

In the coastal areas, where there are already intensive or semi-intensive shrimp farming exists, the proper planning is needed to take some remedial measures which would help in shrimp farm management and take care of the environmental conditions and would lead towards sustainability. In the places like Mekong Delta (Vietnam) and at Kung Kraben Bay, due to the proper planning, all the conflicting activities are separated carefully and now they are enjoying all the benefits of shrimp farming, mangrove conservation and protection of coastal areas. Accurate and comprehensive scientific data are main elements of the planning of natural resources (Barg and Phillips, 1997).

For the proper planning and formulation of policies and to do micro/macro level development planning, some important data and information are required in desired time. This information includes information of existing Land use and Land cover pattern, spatial distribution and other change-related information. To avoid the disturbances in the ecological conditions and create an environment-friendly coastal aquaculture program of the densely populated areas, proper planning, motivation and regulation is needed (Rajitha et al., 2010).

Planning activities for the growth of shrimp culture in different countries or in a broader region inherently have a spatial component. It is just because the variation of biophysical, as well as socio-economic components, varies from one location to the other. Government agencies which are responsible for issuing permits for aquaculture need to do the spatial component analysis for a proposed site. Better management and land wise use requires precise and timely changes in size and nature as well as the spatial balance between exploitation and regeneration. According to Osleeb and Khan (1999), this decision cannot be considerably pointed without the involvement of remote sensing and GIS.

Kapetsky and Travaglia (1995) have mentioned that every single investor need some important information regarding biophysical and social-economic characteristics for their future shrimp farming at the time of site selection. GIS is a tool which can actually help to resolve this problem and is already being successfully used in different places. The extreme need of data to be accurate, with high precision and in systematic manner made Remote Sensing and GIS an extremely reliable and suitable approach for the assessment of resources and to maintain sustainable environmental conditions.

2.4 Remote Sensing and GIS

Remote sensing and GIS can play a major role in geospatial information, social economic and environmental impacts and provide information on soil, water quality, Land use and Land cover, productivity, infrastructure to develop sustainable shrimp culture. This tool is very beneficial for the sustainable development of shrimp culture. It is a transparent process hence to maintain the natural habitat, protect the environment, taking care of the agriculture areas are possible by selecting proper site for shrimp culture.

2.4.1 Remote Sensing

Remote sensing is the technique to collect information about object or phenomenon from measurements made at a distance from the object by satellite imagery or aerial photography. In recent years, the significant spatial and temporal data technology, especially the application remotely sense data has been widely used. Remote Sensing can provide information on wide areas or inaccessible areas in regular intervals based on its multi-spectral character and synoptic coverage. A large variety of images are available from satellites. Every day to collect a large amount of information/data both the sensors (active and passive) operate from the microwave to the ultraviolet regions of the electromagnetic spectrum (Bhatta, 2011).

2.4.1.1 Satellite data

A large number of earth observation satellites are set up on their specific orbits, and those satellites provide many images of the earth's surface to collect valuable information including those about Land use and Land cover (LU and LC). The only way which is capable of collecting data or information on the appropriate time scale at the spatial scale of Earth is Remote Sensing with their high spatial resolution. Indian Remote Sensing Satellite (IRS 1A-1B-1C-1D-P6), Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) are utilized for collection of information on LU and LC. With the improved spatial resolution of latest Indian satellites IRS-1C Linear Imaging Self Scanner (LISS III), IRS-1D (LISS III) and IRS-P6 (LISS IV) extracted data can be mapped to the scale of 1:25,000. The combination of PAN (panchromatic information) data and LISS III data are extremely useful (Jensen, 1996) to collect the spatial information, especially the detail about reclamation and ecologically sensitive areas including salinity, mangroves etc. These ecologically sensitive areas are very important for LULC change detection and for the management of aquaculture.

The uninterrupted flow of Landsat data are provided by ETM+ abroad Landsat 7 which better capabilities of Remote Sensing. With the inclusion of 15 m of the panchromatic band, and six 30 m resolution multi-spectral bands, a long wave spectral multi-spectral band ETM+ replicates the successful Thematic Mapper instruments over Landsat 4 and 5. It has enhanced the capabilities of Thematic Mapper instruments. By ingress of the sea water, the coastal agriculture lands are severely affected. With the help of the images collected for pre and post-monsoon season by Landsat TM salt encrustation, saline, slightly saline and non-saline areas can be easily determined. (Rajitha et al., 2007)

The remote sensing applications using QuickBird-2, WorldView-1 and WorldView-2 have proliferated into almost every facet of development. WorldView-1 and WorldView-2 improved their spatial resolution and the data can be used for mapping up to 1:500 to 1:5000 scales. This data is very useful and now continuously in use to estimate the area of agricultural crop and the production. For the mapping of LU and LC, mapping of the flood and to monitor drought, the same data is widely used. The data is also capable of helping management of water resources, survey and management related to ocean or marine, management of resources of forest and its survey, management of wetland etc. (Bhatta, 2011).

For the enhancement of land-water boundary delineation and vegetation characteristics FCC (False Color Composites) made by using red (0.62– 0.69 mm) and infrared (0.77–0.86 mm) are useful. Details of the sensors applicable to the LU and LC mapping and aquaculture development studies are shown in Table 2.1. The high-resolution images mentioned above are advantageous in case of resolution but are very expensive. Doing temporal mapping for a large area is not really cost–effective (Rahman et al., 2011). Hence the Google Earth images are the alternative suitable solution for LU and LC mapping. This is because Google Earth images give a precise observation of individual buildings, roads, waterbodies etc. and it is completely free of cost. Google Earth also updates the latest satellite images with resolution less than 1 m. Previous images are also available along the updated images and hence change detection can be done easily (Ohri and Poonam, 2012; Jacobson et al., 2015).

Table 2.1 Details of sensors used for Land use and Land cover mapping and aquaculture developments studies

Satellite	**Sensor**	**Spatial Resolution (m)**	**Spectral Band**	**Temporal Resolution (Day)**
IRS-1C & IRS-1D	LISS III	23.5	VNIR	24
	PAN	5.8	VNIR	5
	WIFS	188	VNIR	5

Contd…

IRS-P6	LISS III	23.5	VNIR	24
	LISS IV	5.8	VNIR	5
	WIFS	188	VNIR	5
Landsat - 4,5	TM	30	VNIR, MIR	16
		120	TIR	16
Landsat - 7	ETM+	15	VNIR	16
		30	VNIR, MIR	16
		60	TIR	16
DigitalGlobe	QuickBird-2	2.5	VNIR	3.5
		0.61	PAN	3.5
	WorldView-1	2.5	VNIR	5.5
		0.5	PAN	5.5
	WorldView-2	1.84	VNIR	3.7
		0.46	PAN	3.7

2.4.1.2 Image interpretation

For the object identification purpose and to assess their significance, image (satellite imageries) interpretation process is used. Visual image interpretation includes detection, recognition, identification, classification and delineation of objects in a satellite image.

The Remote Sensing experts test response of many materials, and then they can describe an object based on its composition. To classify multiple features in a scene into different meaningful classes is one of the essential uses of remote sensing. The image then provides various thematic information and a thematic map is obtained (the theme is selectable, e.g., land use, waterbody type, vegetation type, geology). An unsupervised classification is created where features are separated on the basis of their spectral characteristics and a supervised classification is done where prior knowledge of the classes in a scene are used for setting up training sites for the estimation and identification of spectral properties of individual class (Kumar, 2005) and on-screen digitization, the process expert manipulating of digital value for picture elements of an image by using a computer. It usually refers to extracting coordinates from raster image to create vector data.

Several features are there for image interpretation that helps the interpreter to detect and identify objects in the image (Jensen, 1996). The elements to be considered during interpretation of satellite images are:

- Tone: The relative brightness or colour of an object in an image or photograph. It is the fundamental element for distinguishing target of features in an Image.
- Shape: The general form, structure or boundary of an object for example, straight edge shape waterbody represent aquaculture pond and straight linear waterbody represent canal.
- Size: It is a function of scale. Relative sizes of objects are the important key to distinguish them on image or photographs. The absolute size also aids in image or photograph interpretation.
- Pattern: It refers to some unique orderly repetition which is similar to tone with spatial arrangement of visible discernible objects.
- Texture: Texture is considered as the frequency of change or variation in tone of an area shown as an image or a photo. In small area grey level changes hugely in case of rough textures whereas very small tone variation is observed in case of smooth textures.
- Shadow: Shadow refers to both shape and size which can be used to readily reveal its identity.
- Association: Sometimes the objects which are difficult to identify, can be identified on the basis of its recognizable nearby objects, for example, most shrimp farms are located near river estuaries or backwaters, where the water is slightly salty.

For quantitative measurement of LU and LC changes at landscape scale, remote sensing is considered as the most accurate and useful data source (Hudak and Wessman, 1998). There is a huge reflection of the interaction of human activities with the environment. Because their location and magnitude heterogeneous the remote sensing technique can be used for multi-temporal monitoring (Singh, 1989).

2.4.2 Geographic Information System (GIS)

Information system that works with geographical data is known as Geographical Information System (GIS). GIS helps in decision making on the basis of processed data or information. The entire flow of the system consists of observation, data collection, analysis etc. To achieve the purposes GIS should have a full function range. Decision making as well as measuring data, forecasting, describing data or events, forming explanations etc. are the integral parts of the purpose. Spatial data (geographically referenced data) and non-spatial data (attribute) both are used in GIS platform. GIS also helps in spatial analysis (Bhatta, 2011).

Nath et al. (2000) has described in details about the GIS terminology and also explained the GIS process and workflow elaborately to prepare projects on aquaculture on GIS framework. No matter the culture is national, regional or sectorial aquaculture GIS technique is beneficial of all kind of aquaculture (Ali et al., 1991; Meaden and Kapetsky, 1991; Nath et al., 2000). In Africa and Latin America, many large-scale studies are carried out at the continental level (Kapetsky and Nath, 1997). The highest priority should be assigned to the activity with a maximum level of environmental suitability as well as the minimum negative impact on the ecosystem.

2.5 Remote Sensing and GIS application on shrimp farming

To identify the coastal shrimp farming areas and to know the exact location, extent spatial and temporal changes, satellite remote sensing technique is most suitable (Populas and Lanteri, 1991). Such studies are observed in Tamilnadu coast by Krisnamurthy et al. (1993), in West Bengal along with Gujrat coast by Nayak et al. (1995), in Bangladesh coast, explained by Shahid et al. (1997). Hein's (2000) research work discloses that total 80% of the mangroves of the study area have already converted to shrimp farms.

Hossain et al. (2003) focused his research work in Kandleru creek area of Andhra Pradesh. He monitored the development of shrimp farming from space. It was a Remote Sensing and GIS approach, and it encompasses an area of 256.64 km^2. From his study, drastic changes of LU and LC can be found with the information about the dramatic increment of shrimp culture of the study area. By using LISS-II, LISS-III and PAN image interpretation this study explains elaborately about the growth of shrimp farming in Kandleru area on the basis of data noticed from 1988 to 2001. Around the creek, many places where there were mangroves before were converted to shrimp farms. An uncontrolled, unmanageable, unplanned shrimp culture growth has been detected as a result of his study.

Sanchez et al. (2003) established his research within the Ceuta coastal lagoon system, Mexico, considering the changes in LU and LC by using multi-temporal satellite imagery of Landsat. He examined the global change trend of shrimp culture and the effect of newly established shrimp farming industry on the natural cover. Helpful information categories namely secondary succession, mangrove, dry forest, lagoons, bare substratum, irrigated and temporary agriculture, shrimp ponds and villages were assessed and evaluated on the two images of year 1984 and 1999.

2.6 Remote Sensing and GIS studies on Environmental Impact Assessments

Rajitha et al., 2007 had briefly described the status of shrimp culture development in India. They had also included in details about the ecological and social-economic impacts of shrimp farming and recommended measures to attain sustainability by utilizing advanced tools like remote sensing and GIS. Manjarrez and Ross in 1995, have explained the formulation of environmental models to help land based development of aquaculture based on GIS frame work, in the state of Sinaloa, Mexico.

By integrating the suitable parameters of shrimp culture using GIS technique Islam et al, (2009) has found out the potential shrimp farming areas of Bangladesh. Parameters considered are thematic information of water and soil quality, facilities of infrastructure, river courses and are integrated by using GIS and found out the potential areas of semi-intensive shrimp farming areas. The result of this study is also verified in the field and is comparatively reasonable. But the accuracy of this type of study is highly dependent on the quality of input data. This study also demonstrated the capability of GIS technique for sustainable shrimp farm development.

2.7. Remote Sensing and GIS based site selection of aquaculture

Details of studies for the site selection in aquaculture using Remote Sensing and GIS are explained in the Table 2.2 Numerous works have been done concentrating wide geographical areas, with large regions, selecting a state or even considering entire country and were mostly focused on aquaculture planning (Manjarrez and Ross, 1995).

Table 2.2. Details of previous documentation on Remote Sensing and GIS based site selection for aquaculture

Region/Country	**Objective**	**Culture species**	**Author(s)**	**Year**
U.K	Siting trout farms	Rainbow trout	Meaden	1987
Malaysia	Regional suitability for fish and shrimp	Fish and shrimp	Kapetsky	1989
Pakistan	Siting carp farms	Major carps	Ali et al.	1991
Chile	Cage, pen and bed culture	Salmonids and mussels	Krieger & Muslow	1990
USA	Regional catfish and crawfish potential assessment	Catfish	Kapetsky	1990
U. K	Sites for salmon culture	Salmonids	Ross et al.	1993
Norway	Siting salmon	Salmon and rainbow trout	Ibrekk et al.	1993
Africa	Warm water fish culture sites	Nile tilapia	Kapetsky	1994
Mexico	Regional aquaculture model for shrimp culture	Shrimp, Vannamei shrimp	Manjarrez	1996
Vietnam	Potential for rice and fish culture	Prawn and fish	Thu and Demaine	1996
Latin America	Continental assessment for Tilapia, carp and tambaquipacu culture.	Tilapia, carp and tambaquipacu culture	Kapetsky and Nath	1997
Canada	Regional suitable site for Mussels, oyster.	Mussels, oyster	Habbane et al.	1997
Africa	Warm water fish culture site selection	Tilapia, catfish, and carp	Manjarrez and Nath	1998
Bangladesh	Suitable site for brackish prawn,	Giant prawn	Salam and Ross	1999
Florida	Sites for hard clam culture	Hard clam	Arnold et al.	2000
Bangladesh	Site selection for shrimp farming	Tiger shrimp	Quader et al.	2004
India	Site selection for shrimp farming	Tiger shrimp	Rajitha et al.	2007

2.8 Guideline for sustainable shrimp farming in India

During mid-eighties, the commercial shrimp farming has started spreading its roots in India. Compared to the neighbour Asian countries this start is really late. In countries like China and Taiwan shrimp farming had gone too far by that time. In India due to improper farm managements and due to lack in scientific practices it has faced many problems since the beginning. Commercial shrimp farming has boomed in India in the year 1990 and in between 1995 to 1996 the shrimp farming has spread many viral diseases. Actually, the main fact is that almost all the coastal states in India were very new to commercial level of shrimp farming and production and hence there were no good farm practices and lack in suitable extension services which in turn led to too many complex problems (Yadava, 2002). The guideline for sustainable development and management of brackish water aquaculture by the Ministry of Aquaculture has given the proper measures for the discharged waste water from the shrimp farms. After fair comparison of parameters of shrimp culture waste water for releasing to the open waters, it is seen that the standards of India are fairly strict, specially in case of free ammonia and nutrients (Table 2.3).

Table 2.3 Guidelines/standards for waste water management for Indian aquaculture farms

Sl. No.	**Parameters**	**Final Discharge Point**	
		Coastal marine waters	**Creeks/ estuaries- when the same inland water courses are used as water source and disposal point**
1	pH	6.0-8.5	6.0 - 8.5
2	Suspended Solids mg/l	100	100
3	Dissolved Oxygen mg/l	Not less than 3.0	Not less than 3.0
4	Free Ammonia (as NH_3 -N) mg/l	50	0.5
5	Bio-chemical Oxygen Demand (BOD) (5 days at 20°C) mg/l	50	20

Contd...

6	Chemical Oxygen Demand (COD) mg/l	100	75
7	Dissolved Phosphate (as P) mg/l	0.4	0.2
8	Total Nitrogen (as N) mg/l	2	2

Proper treatment of farm effluents is really necessary in order to achieve the waste water quality standard. The present guideline of ETS (Effluent Treatment System) is very helpful for all the shrimp farms to achieve their objectives.