Chapter 1
Introduction and Literature Review

Recently, there has been a lot of enthusiasm near the fishery, especially with rapidly increased global demand. In India, the fishery is an important economic activity and rising field with diverse resources and possibilities. Fishery resources are classified into two major classes, based on their sources which are inland and marine fishery resources. Inland resources are those that can be collected within the land water resources. On the other hand the marine fishery resources are collected from the open ocean water. The productions of fishes are increased with demand. A statistics of the fish production data has been analyzed from the year 2003 to 2014. According to the Handbook on fisheries statistics, 2014, inland fishery resources and production are increased during over the last few years (Figure 1.1).

Andhra Pradesh is the top fish producing state in India. During 2014-15, the state Andhra Pradesh (1st) and west Bengal (2nd) has produced 1964.43 and 1617.319 ('000 tones) fishes in that order. Andhra Pradesh, West Bengal (WB), Gujarat, Kerala and Tamil Nadu are the five major fish producing states (Figure 1.2). In West Bengal, the majority of the population has listed fish as a main course in their regular menu. Therefore; the demands of fishes are increasing day by day in West Bengal.

In 2015-2016, the state's (WB) required demand was approximately 16.96 lakh ton whereas the state produced 16.71 lakh ton as a result, 0.24 lakh ton deficit in fish production was noted. Among the produced fish, 14.93 and 1.78 lakh ton was from inland and marine fishing sectors respectively. Year wise details of demand and production scenarios are given in Table 1.1.

Table 1.1: Demand and production of fish in West Bengal (2009-16)

Year	**Demand (lakh ton)**	**Production (lakh ton)**			**Deficit or Surplus (lakh ton)**
		Inland	**Marine**	**Total**	
2009-2010	15.62	13.26	1.79	15.05	(-) 0.57
2010-2011	15.85	12.46	1.97	14.43	(-) 1.42
2011-2012	16.06	12.90	1.82	14.72	(-) 1.34
2012-2013	16.29	13.38	1.52	14.90	(-) 1.39
2013-2014	16.51	13.92	1.88	15.80	(-) 0.71
2014-2015	16.72	14.38	1.79	16.17	(-) 0.55
2015-2016	16.95	14.93	1.78	16.71	(-) 0.24

Source: Hand book of fisheries statistics, 2015-16

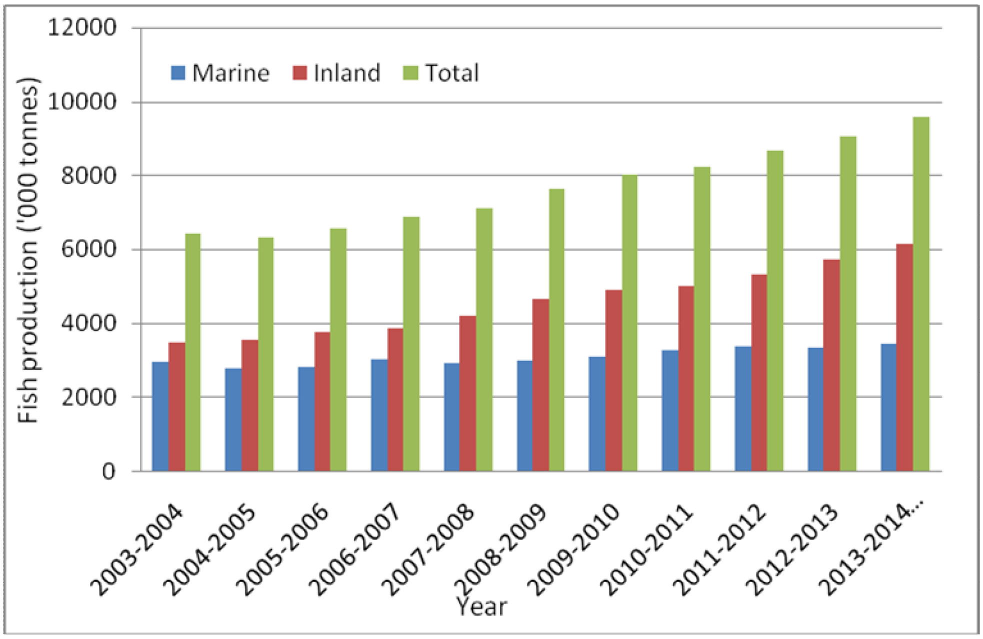

Figure 1.1 Fish production in India during 2003-04 to 2013-14
(Source: Hand book on fisheries statistics, 2014)

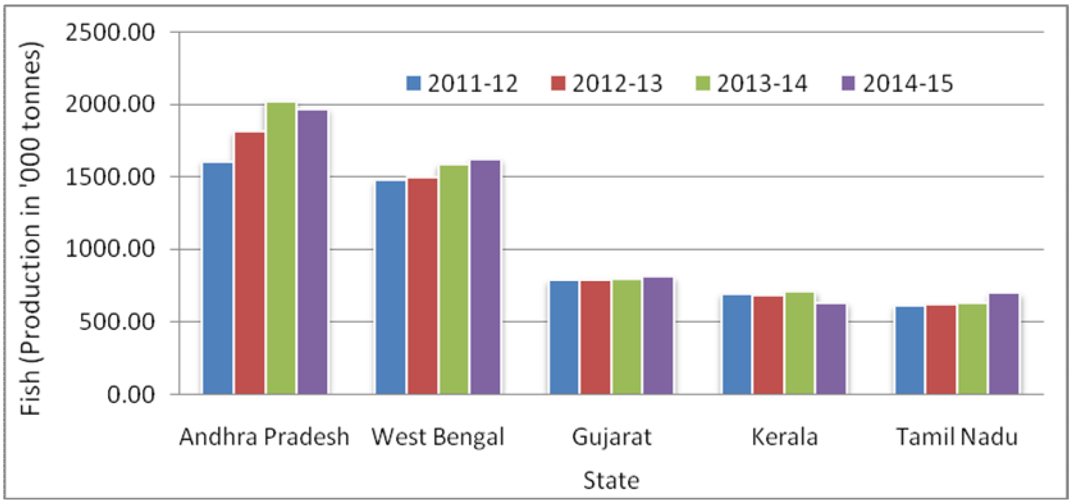

Figure 1.2 State wise fish production in India (during 2011-12 to 2014-15)
(Source: Handbook on fisheries statistics, 2015-16)

Purba Medinipur district is one of the most potential fish farming areas of West Bengal state. This district is facing a decisive problem in the monsoon. The fish farming is hampered by drainage congestion, flooding and bank erosion (Acharyya et al., 2015). The flood, bank erosion, drainage system, water quality etc. rapidly effects on the fish cultivation of the area. These parameters generally influence the inland fish productivity and fish diversity directly or indirectly.

In need of economic melioration and improvements of fish cultivation, there is a necessity for the analysis of the different socio-economic and natural fish growing environmental parameters. Mainly the inland aquaculture in this region affect by fresh water. Here, freshwater fish means, those fishes lives with <0.05% of salinity of water (Wikipedia, 2018) like lakes, rivers, ponds etc. Small variation in freshwater quality may affect growth of the fish species as they are 'ectothermic' (Moyle and Cech, 2004; Karmakar et al., 2018). Therefore, the spatial distribution of fish species, their standardize growth, quality of their living water etc. are important in this research.

Remote sensing and Geographical Information System (GIS) may have a prospective tool to analyze the spatial data distribution of fish species and their corresponding quality of fresh water. GIS also proved its potentiality for database generation, data interpretation, mapping and advanced representation of the geospatial information etc. in a compact package (Nisha et al., 2017). Hence, the GIS technique has been considered for mapping and analysis in this research work.

1.1 Research Objectives

The main research work is demonstrated through some major objectives based on the problems of the study area. The focus of this study is about these three aspects which are as follows:

1. To monitor and map the detail water resources and to study the water changing scenario of the region.
2. To document the fish diversity status of the study area.
3. To estimate the site suitability classes and analysis of potential conservation areas for aquaculture.

To achieve the objectives the following specific issues need to be addressed.

- What are the existing scenarios of the study area?
- Are there any scopes for mapping and analysis the fish diversity, quality of fish living water, fish growth and their production, potential site selection assess in GIS environment?
- Are there any scopes for temporal analysis of socio-economic environment?

- What are the spatial distributions of the inland impounded water bodies?
- What are the systematic procedures of fish diversity analysis?

1.2 Literature Review

A comprehensive literature review has been made to understand the objectives related to the research. The study of the literature review has been done from many journals and papers, books, scientific reports and publication, internet etc. These studies of literature provides the level of scale to understand the subject area, importance of the research, provide some statistical data, understanding of geospatial data and good grip in knowledge. Some of them are described below.

1.2.1 History of fish farming

The fish farming has actually been running for thousands of years. The fish cultivation or aquaculture has converted from 'humble beginning' into fishing industry, today (Julie, 2016).

The hieroglyphics and ancient manuscripts provide the proof of aquaculture near about last 4,000 years. In 475 BC, Fan-Lai (Chinese man) wrote a book called 'The Classic of Fish Culture to teach others how to raise fish for food'. In 1733 the modern form of aquaculture, established by Germany and successfully gathered fertilized fish eggs. Since then, fish farming has continued to develop in different centuries with different technique and research. Now, the fish farming takes place in ponds, tanks, pens or re circulating tanks and even in rice cultivation fields (Halwart and Gupta, 2004). For over 2000 years, the fish and rice cultivation makes a tradition in Southeast-Asia.

1.2.2 Aquaculture

As defined by the United Nations Food and Agriculture Organization (FAO), aquaculture is the “farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. The meaning of farming indicates some kind of involvement in the process of rearing to increase the production rate, such as regular stocking, feeding etc. Farming also implies individual or community ownership of the stock being cultured…”

According to Joao et al. (2013), Aquaculture has a lot of similarities to agriculture; it is a cultivation of aquatic organisms into a managerial system based on the interaction among environment and human being. The aquaculture has been categorized as:

1.2.2.1 Ecological aquaculture

Ecological aquaculture that is uses environmental principles as an example of aquatic development (Costa, 2003). All plans and activities (such as designs, monitors, etc.) are performed based on the natural and social environment in which they live. Ecological aquaculture farms are known as integrated aquatic ecosystems that are developed to provide social-economic benefits (Barry, 2013).

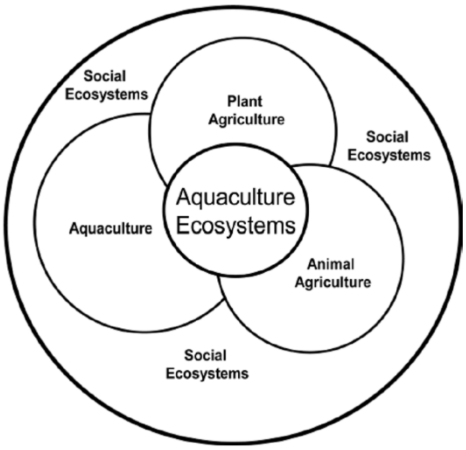

Figure 1.3 Outline and functions of aquaculture and natural ecosystems.
(Source: Barry, 2010)

1.2.2.2 Organic aquaculture

Organic farming is a natural method and process that is eco-friendly and healthy, in co-relation with nature and does not use toxic chemicals. Organic aquaculture is the farming of aquatic plants not including the use of antibiotics, chemicals and fertilizers, preserving the environment and biodiversity of aquatic animals such as bivalves, shrimp, fish, etc. and hydrophytes (Dube and Chanu, 2012).

All India Federation of Organic Farming (AIFOF) accepts and used the standard documents by International Federation of organic Agriculture Movement (IFOAM, 1981) which are as follows (IFOAM, 1972; Dube and Chanu, 2012; Gould, 2019):

1. To work as best as possible in a closed system and draw on local resources.

2. Maintaining of soil productiveness in long period.
3. To all kinds of pollution that can result from agricultural farming techniques.
4. Produce high nutritional quality and adequate food intake.
5. Minimizing the use of fossil fuels in agricultural sector.
6. Providing living conditions of life that align with their physiological needs and humanitarian principles.
7. Make it possible for farmers to earn a living through their work and to develop their societal aspects.

To which AIFOF has added the following:

8. Proper technology is to be developed based on understanding of biological system.
9. Using a decentralized system for product processing, distribution and marketing.
10. To create a system it is aesthetically pleasing both within and outside the system.
11. Management of wildlife and protect their habitats.

1.2.2.3 Monoculture

Monoculture is the procedure of aquatic organisms of single fish species in the same pond (Ali et al., 2017). The advantage of monoculture fish farming is that (1) it enables the farmer to produce a feed that can meet the needs of a particular fish species, especially in the acute culture system. (2) Fish of different ages can be stored whereby selective yield is increased (Sah and Mehta, 2018; Paruntu et al., 2018).

1.2.2.4 Polyculture and integrated aquaculture

Polyculture farming is a traditional and integrated agriculture-aquaculture system (Neori et al., 2004; Popp et al., 2018). Polyculture is the process of culture of aquatic organisms of multiple species in the same pond (Costa et al., 2013; Singh et al., 2020). The scientifically polyculture and research started in the 1950s (Brzeski and Newkirk, 1997; Neori et al., 2017). The inspire ethics is that fish production in ponds can be maximized by combining species with different dietary habits. The conviction of polyculture of fish is the total use of different trophic level of food chain and spatial niche in the pond to get maximum fish production per unit area (Singh et al., 2020; Manual on polyculture.., 2020).

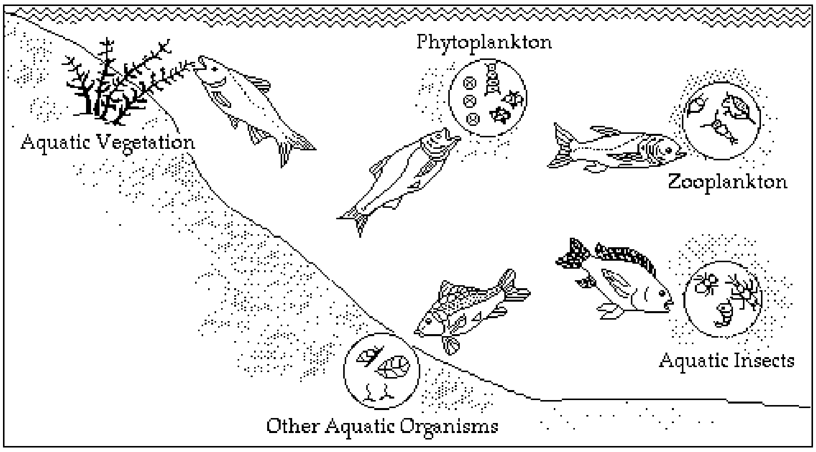

Figure 1.4 Polyculture utilizes natural foods efficiently
(Source: Singh et al., 2020)

1.2.3 Bio diversity and Fish

Biodiversity is the variations amongst living organisms from all the origin points, including earthly, marine, and other ecosystems and the environmental complexes of which they are incorporated and this comprises diversity within species, between species, and of ecosystems (Millennium Ecosystem Assessment, 2005). While Earth's biodiversity is so affluent that most of the species are yet to come across, many species are being menaced with the verge of vanishing due to human activities, putting the Earth's magnificent biodiversity at jeopardization (https://www.nationalgeographic, 2020). Biodiversity is categorized into several major levels:

A. Genetic diversity

This is the genetic information contained in the organisms that live in different flora, fauna, and species populations. It is known as a genetic variation between the population and species (Conservation of Biodiversity, 2020; Rawat and Agarwal, 2015).

B. Species diversity

Species diversity is the variety of species within the habitat. Species are the fundamental units of biological categorization. Species richness is the expression to describe the number of different existing species in a specified region. Therefore, species diversity is further classified into (a) Species richness: Number of species in a unit area (b) Species Evenness: It is represented in a region of each species with which it implies comparative abundance (Rawat and Agarwal, 2015).

C. Ecosystem/ Community diversity:

It deals with a variety of living organisms, biotic communities and ecological processes (Rawat and Agarwal, 2015). A mountainous region that contains lakes, grasslands and forests will have the advantaged biodiversity in this cause (Types of Biodiversity, 2020). Manda (2020), classified the Community diversity into three level, (a) Alpha diversity: It refers the biodiversity of a particular area or region, community and or ecosystem. (b) Beta diversity: This diversity involves to the measure of a biodiversity which facilitates by comparing the number of species divested between environmental or ecosystems slopes. (c) Gamma diversity: It is the biodiversity of the total species richness over a large region.

D. Functional Diversity

The way species act, acquire food and utilize the natural resources of an ecosystem is known as functional diversity (Types of Biodiversity, 2020). a) Functional types: species execute diverse ecological functions. b) Functional analogues: Functional analogues represent distinct taxa performing the same or very similar ecological functions.

E. Global diversity

The total number of flora and fauna on this planet is astounding. According to the IUCN (2004), the total number of flora and fauna are about 1.5 million (Conservation of Biodiversity, 2020).

Fish diversity of fresh water basically represents the diversity and richness of fish and which supports the commercial fisheries (Shukla and Singh., 2013). Fishes are the keystone species which control the distribution and richness of other organisms within the ecosystem (Moyle and Leidy, 1992). India ranks ninth in the world in terms of greater freshwater biodiversity. Universally almost 450 families of freshwater fishes existed and approximately in India they are 65 at present (Samal et al., 2016). A group of about 2500 species depicting miscellaneous characteristics, of which 930 species belonging to 326 genera, located mainly the inland waters of India (Jayaram, K, 1999).

Fish diversity mostly rely on the biotic and abiotic factors and sort of the eco system, age of the water body, mean depth, water level fluctuations, morphometric features and have great ecological implications (Kumar, 2004). The hydro biological influences also play an effective role in fisheries output to a great extent (Murugan et al., 2012). In the recent times several large scale studies have been acknowledged modifications and loss of aquatic habitat as primary factors frightening the preservation of freshwater fishes and communities (Hewitt et al., 2008). These factors determine the status of fish species affluence or assemblages in a particular region.

1.2.4 Sustainable aquaculture

The concept of sustainable development was revealed in a conference of 'United Nations Conference on the Human Environment (UNCHE)' held in Stockholm, Sweden, in 1972 (Fezzardi et al., 2013). Fish farming is an economic activity and it is directly dependent on the quality of the environment, all anthropogenic efforts and interest should be shown to preserve the environment for long term activities (Pillay, 1990). Therefore, the sustainability of aquaculture is depending on three dimension concept (Figure 1.5). The idea about the fisheries resource development and use should be closely related to the conservation (FAO, 2005–2012). The International Union for Conservation of Nature (IUCN) constantly updates about their red list status.

There are five ways that can reduce the aquatic environmental footprints and push the aquaculture industry to become more sustainable (World Economic Forum, 2018). Those are:

a. Move inland
b. Move offshore
c. Utilize multi-trophic aquaculture
d. Invest in new renewable energy sources
e. Eat sustainable seafood

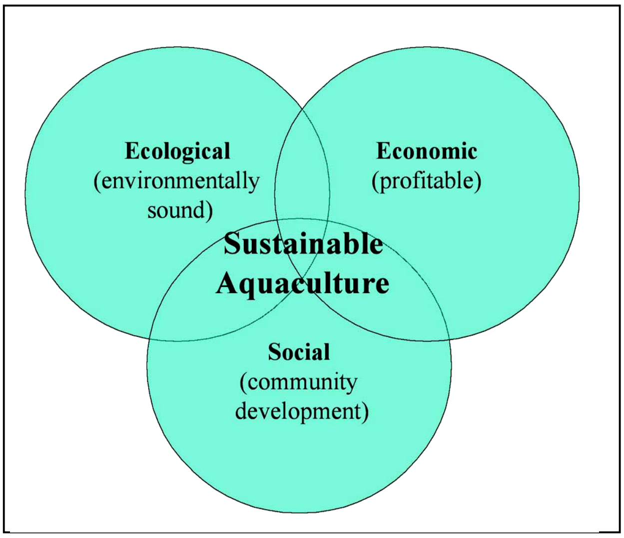

Figure 1.5 Dimensions of sustainable aquaculture
(Kathryn et al., 2004)

1.2.4.1 Inland fisheries

Most recreational fishing takes place in inland fishing. Over the past two decades, both capture and fish cultures have recorded remarkable growth and change in India's indigenous fisheries (Katiha et al., 2005). Inland fisheries must relate with other uses of freshwater in a lake, reservoir, ponds and river etc. More than 90 percent of all inland or freshwater fisheries are allied with developing countries, such as Bangladesh, Indonesia, and India etc. and most are consumed locally (Das, 2007; Constantineanu and Constantineanu, 2018). There are two type of inland fishing: (1) fish capture from natural water body, (2) Another is fish farm, where fish are flourished in ponds, reservoirs, tanks and impounded water body etc typically for human consumption. The impounded water bodies and fisheries are categorizes base on geometric scale or area (Small, Medium Large scale fisheries) (Mandelbrot, 1967). Fish farming is related to breeding, feeding, and harvesting etc (Inland Fisheries, 2020). The breeding, feeding, and harvesting are also dependent on the socio-environmental footprint of the cultivated area.

1.2.4.2 Socio-environmental footprint of Inland fisheries and aquaculture

Inland water resource such as rivers, ponds, reservoirs, wetlands and lakes are major sources of aquatic fish. (Bandyopadhyay et al., 2014; Acharyya et al., 2015). The fish diversity is influenced by the human in different ways. Fresh water ecosystems are declining continuously due to human intervention (Mukherjee et al., 2002). The existence of aquaculture mainly depends on the adequate water quality, potential landscape, Soil, climatic condition, anthropogenic activities and pollution etc (SMERAA, 2010). The aquaculture site selection procedure that identify inland areas depends on existing socio-environment conditions (Kovari, 1984; Aguilar-manjarrez et al., 2017), divides the elements of site selection into three broad categories: (1) ecological; (2) biological; and (3) socio-economical.

Table 1.2 Overview of dredged material containment area site selection factors

Factor	Criteria
Land use	Land use in the area and Material disposal should be compatible
Water quality/hydrology	Water quality not effect in long period.
Soil characteristics/ geological conditions	No leachate migration to groundwater; good foundation soils.
Meteorological conditions	Sites not subjected to flooding, runoff, extreme winds.
Access	Construction of access routes possible.
Environmental concerns	Environments and historical features of the area must be protected.
Social	Public input required for sites near populated areas.
Institutional	Regulations on material disposal and land use must be identified.
Economic	Building cost and operating site, protection of environment, pumping/transportation acceptable.
Population density, market and communication	Rising fish demand is related with the growing rate of population. The availability of potential fish market and rail-road near the aquatic site is an important factor to feasibility and distribution.

Source: Homziak et al., 1990; Manjarrez and Ross, 1995.

Table 1.3 Environmental parameters and suitable criteria for aquaculture

Parameters	Criteria	References
Soil	**Clay** • The best soil types for making fish ponds is sandy clay to clayey loam. • Less than 20% clay content is unsuitable and more than 50% is appropriate. **Organic** • More of organic matter in the soil is harmful. • Organic soil layers more than 0.6 m deep are inappropriate for ponds based fish culture, due to excessive seepage will cause damage when the	Hossain and Das 2010. Nayak et al., 2014. Assefa and Abebe, 2018. Kovari 1984. Lawson, 1995. Boyd, 1995. Boyd et al., 2002.

	organic layer deteriorations occurs. **pH** • Ideally, the soil pH of the fish pond should be between the pH values of 6 to 9.	
Water	**Salinity** • Some freshwater species can alive in 1-2 g/l salinity.	Lawson, 1995.
	pH • pH is mainly influenced by the concentration of carbon dioxide. • Suitable pH range from 6.5 to 9. • pH become stressed in between 4.0 to 6.5 and 9.0 to 11.0.	Boyd, 1979. Bhatnagar and Devi, 2013. Ekubo and Abowei, 2011.
	DO • Fish growth, survival, behavior and distribution are also dependent on DO. • 3.0-5.0 ppm is unproductive • > 5.0 ppm is good	Solis, 1988. Banerjea, 1967.
	Temperature • 27.6^{o}C to 30^{o}C is most favorable for aquaculture. • 28^{o}-32^{o}C is much endurable for tropical major carps	Bhatnagar and Devi, 2013. FAO, 2006.
	TDS • Less than 400 ppm is good for fish culture.	Aquariums and Aquaculture, 2019. U.S. Environmental Protection Agency, 1986.
Rainfall	• Annual rainfall of >1200 mm is generally suitable for fish farming	Kapetsky, 1994. Assefa and Abebe, 2018.
Slope	• < 3 % is suitable, 3-8% is moderately suitable and, > 8% is unsuitable for aquaculture.	Kebede et al., 2015.

1.2.5 Species and fish diversity

From the earliest ages of the living world, people have been using a categorization in their normal live. The word 'species' has been defined as unerringly for over three centuries (Mallet, 1995; Aldhebiani, 2018). The species are one of the most basic biological units for comparison in almost all areas of biology, physiology, paleontology, ecology, genetics, molecular biology etc (Gippoliti, 2018; Groves et al., 2013; Giacoma, 2014).

Species diversity varies from species richness to species because it takes to consider both the number of species present and the control or similarity of the species related to one another. On the other hand, Species richness means the number of species in a specific sample in per unit area (Ashton, 1992; Brown et al., 2001; Aggemyr et al., 2018).

Simpson and Shannon-Weiner used the species richness and evenness to evaluate the diversity in their index (Simpson, 1949; Shannon and Weaver, 1949). The formulae of Simple or Simpson Diversity Index (SDI) or Normal Diversity Index (NDI) is as follows:

$$NDI = N(N-1)/\Sigma n\ (n-1)$$

Where, NDI represents diversity index; N is total number of individuals of all species and n is total numbers of individuals of species. Another widely used information statistics indices that can take into account the rare species in a community, known as Shannon and Wiener index (Shannon and Wiener, 1963).

Compare the diversity in different ecosystems to monitor the progress of conservation measures another most popular method is to use the relative abundance of different species to calculate Simpson’s Index of Diversity. Simpson's index considers the number of species appearance and as well as the relative or apposite to the abundance of each species (https://geographyfieldwork.com, 2018). Simpson’s diversity Index value increases equally with the increase in species richness and evenness. Simpson’s delineate the randomly selected two individuals from a community of possibilities belonging to different species (http://www.biologydiscussion.com, 2018). In this study the survey data was also calculated by the SDI equation presented below.

$$SDI = 1-\{\Sigma n(n - 1)/N(N - 1)\}$$

Where, N is the total number of organisms of all species and n denotes the total number of organisms of a particular species. The result value of diversity index (SDI) ranges between the 0 and 1, 0 represents the infinite diversity and 1 denotes no diversity. So the bigger value represents lower diversity. But it does not sound logical, so to get over this problem SDI is often subtracted from 1 that is (1-SDI). The SDI is best applicable on a community with fewer and dominant species (Ecology and Simpson’s Diversity Index, 2008).

Further the most commonly used index in bionomic studies is SWI. The SWI diversity incorporates both, strength for provides a simple-synthetic summary and weakness for difficult to compare differ greatly communities (Kerkhoff, 2010). SWI estimates that people create arbitrary samples from an independent large number of populace and all species are act in the sample (Bibi and Ali, 2013). The collected fish species of each sampling sites was calculated by the following formula:

$$\text{SWI or } H = n/N*\ln(n/N)$$

Where, H represents Shannon-Wiener index of diversity; n is total numbers of individuals of species, N is total number of individuals of all species and 'ln' in natural log. The SWI values range between 0 to 5 and it usually ranging from 1.5 to 3.5. The index value is rarely more than 4 (Kerkhoff, 2010). The higher value of SWI represents higher species diversity (Jhingran etal., 1989).

Fish species richness depends on the taxa studied and the capability of different survey techniques in detecting uncommon species. There are 50 species belonging to 33 genus and 14 families were recorded during the study in Upper Ganga basin of Himalayan region (Pathak et al., 2014). Total numbers of 251 freshwater fish species were recorded in West Bengal that shows its richness in fish biodiversity (Patra et al., 2017). Different researchers studied in different ways about fish diversity in West Bengal. It's recorded a total number of 37 freshwater fish species in a market based survey in Burdwan district (Saha et al., 2017). Bhattacharya and colleagues (2018) identified 102 fresh water fish species belongs to 10 orders and 27 families in Bankura district. Mandal and Chanda (2017) studied and reported 14 numbers of freshwater fish species in Midnapur town market. In 2008, Bhakta and Bandyopadhyay studied that 11 fish species, 8 genera, 6 families and 1 order have lost between the years 1990 to 2006 in Purba Medinipur district, West Bengal. Therefore, it showed a prominent gradual decline in fish productivity in West Bengal (Das et al., 2011).

1.2.6 Remote Sensing and GIS

1.2.6.1 Remote Sensing approach

In present days the term "remote sensing" generally refers to the use of satellite or aircraft based sensor technologies to identify and categorize different objects on Earth surface. In respect to the type of energy sources it may be divided into active remote sensing (making use of sensors that detects the reflected responses from object that are irradiated from artificially generated energy sources) and passive remote sensing, uses the reflection of natural sources of energy i.e. sunlight (Gupta, 2003; Campbell and Wynne, 2011). There are a number of stages in a Remote sensing process, known as basic principle of remote sensing.

I. Source of energy.
II. Energy interaction with atmosphere.
III. Energy reflected from earth surface/object.
IV. Energy passing through atmosphere.
V. Energy received by sensor.
VI. Data transmission, processing and analysis.

The electromagnetic spectrum (EMS) is the entire spectrum or series (Table 1.4, Figure 1.6) infrared, visible light, ultraviolet light, X-ray and thermal radiation etc (Artiola, 2004). It ranges from meters to nanometers, traveling at the speed of light, and propagating through space like a vacuum (L'Annunziata, 2016).

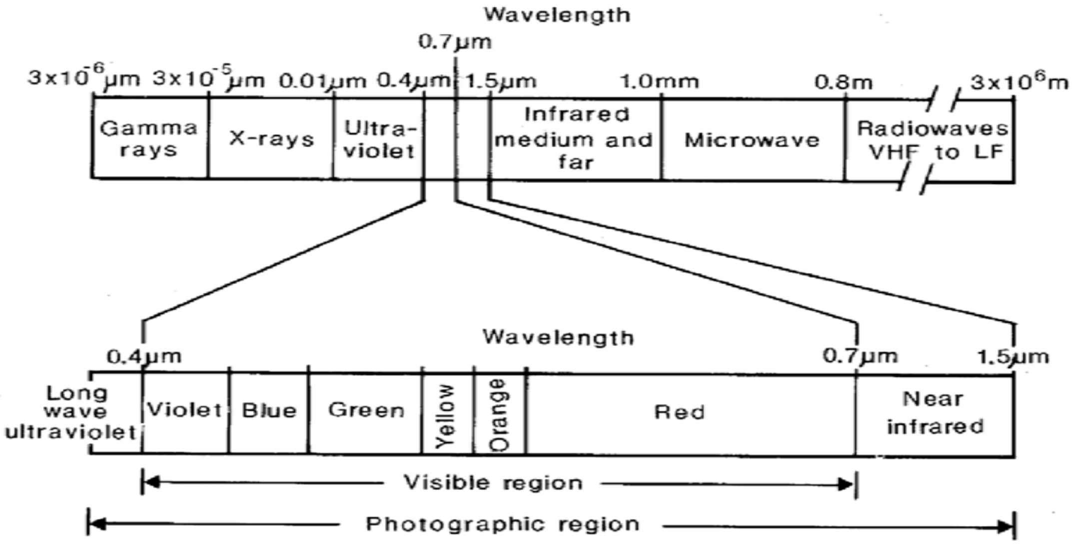

Figure 1.6: The electromagnetic wavelength range spectrum
(Source: Lindgren DT, 1985)

Table 1.4 Electromagnetic radiation (EMR) and their principal

EMR		Wavelength region	Principal / Uses
Gamma rays		< 0.03 nm (Short wavelength but high frequency)	Blocked from Earth's surface by atmosphere
X-Rays		0.03 to 3.0 nm	• Used in medicine • Industry and astronomy • Can cause cancer
Ultraviolet waves		0.03 to 0.4 mμ	• Effect on blindness in humans and skin cancer
Visible light	Blue	0.4-0.5 mμ	Suspended sediments, soil-vegetation differentiation, Atmosphere etc.
	Green	0.5-0.6 mμ	Rock-soil, turbidity, Bathymetry in shallow water, healthy vegetation etc,
	Red	0.6-0.7 mμ	Absorption of Chlorophyll, species detection of plants, soil and geology boundary decimation etc.
Infrared waves	NIR	0.7-1.3 mμ	Biomass, moisture, land and water demarcation, land form study, geology and geomorphology study etc.
	MIR	1.3-3 mμ	
	TIR	3-5 and 8-14 mμ	
Microwaves		1 mm to 30 cm	• Radar • Now used in communication • Medicine and consumer use (microwave ovens)
Radio waves		30 cm to 100 km.	• Remote control devices • Cell phones • Wireless devices etc.

Image processing like atmospheric, geometric and radiometric correction; enhancement is the primary step in remote sensing. Different numbers of filtering processes like noise filter, blur filter, high-pass filter, low-pass filter, band-pass filter, etc. are applied on the satellite image to differentiate the earth's object of interest with greater confidence (Gupta, 2003; Prost, 2014).

After the first environmental observation satellite was launched in 1972, remote sensing has been the primary data source. Over the past five decades, remote sensing technology has come a long way in becoming a mature science. Remote sensing technique is a quite easier process to explore potentially extensive objects on earth surface. The advancements of high resolution of satellite data is now accessible, both spatially as well as spectrally (Rees, 2013; Rahmati et al., 2015). Numerous countries have their earth observation satellites with different sensors used for specific nonmilitary purposes such as land use planning, weather monitoring, air pollution, urban and regional planning, mining-geology mapping, forest and agricultural analysis, wetland mapping etc (Dasgupta and Mukherjee, 2019; Colkesen and Kavzoglu, 2019; Todoroff and Kemp, 2016; Yeh and Wu,1998; Haldar, 2013).

Manju and associates (2005) used the pre and post monsoon satellite data to analyze the wetlands and characterized through aquatic flora and turbidity status. The near infrared (NIR) band is used to delineate the water bodies as the spectral absorption characters of water are clearly separable from other spectral response in the region 0.70 - 0.86 µm. The red band (0.62 - 0.68 µm) of LISS III data is found to be useful for turbidity classification (RRSSC, 2000), as spectral reflectance characteristics of pure and turbid water are clearly separable in this wavelength range.

According to the researchers (Garg et al., 1998; Manju et al., 2005) the pure and turbid water are clearly separable by red band (0.62 - 0.68 µm) of LISS III data. Remotely sensed satellite data can strengthen the abilities of decision-makers to monitor water quality more effectively. Remote sensing techniques have been widely used to assess the qualitative water quality properties in past few decades. High resolution satellite sensors may meet the requirements for monitoring quality status of water bodies. Remote sensing technology is an efficient tool for water quality, water level, water demand, ground water management and flood mapping (Su et al., 2003, Andres et al., 2018). Avdan and colleagues evaluated several different algorithms using Pearson correlation coefficients for total dissolved soils (TDS), water transparency, electrical conductivity (EC), water turbidity, water level depth, suspended particular matter (SPM), and chlorophyll content in waterbody. Hellweger and associates (2004) studied the usefulness of satellite data for analyzing water quality in a harbor of New York and compared ground data from a routine sampling program with imagery from the Landsat Thematic Mapper (TM) and Terra Moderate Resolution Imaging Spectro radiometer (MODIS) sensors.

1.2.6.2 Land Use/ Land Cover

Land use (LU) is indicating the man's activities and their various uses which are carried on land, and land cover (LC) refers to natural vegetation, water bodies, rock/soil, forest cover and others noticed on the land, basically it’s the physical cover of the Earth surface (NRSA, 1989). Land Use/ Land Cover change a regular process over time and space due to major variations in the environment caused by anthropogenic and natural factors. There are different natural causes of land use land cover changes like climate change resulting floods, drought or anthropogenic causes like industrialization or urbanization (Parveen et al., 2018). The LULC pattern of a region depends on various natural and socio-economic factors and their utilization are measured as a central issue for managing and monitoring the all natural resources and their environmental changes (Su et al., 2011). Conventional methods for assembling demographic data and analysis of environmental samples are not sufficient for different environmental studies. Satellite remote sensing and Geographical Information Systems technologies give the opportunity to study and monitor the dynamics of natural resources for environmental management (Berlanga-Robles et al., 2002). Currently the advanced use of digital maps and geo databases, map can be maximized or minimized dynamically for changing the display scale by zooming.

There are numbers of different classifications techniques are exist to produce land use land cover map like supervised classification, unsupervised classification, Spectral base classification (Hyper spectral base) and Vector based classification etc. High resolution datasets are required for Vector based classifications. Pixel based classification are largely used for vast area and it depends on the properties of image pixel value.

Researchers (Kontoes et al., 1993; Franklin et al., 2002; Gallego, 2004) used different advanced classification approaches for improving classification techniques and accuracy. Many factors and challenges are involved in classifying the remotely sensed data into thematic map and its success like complications of land surface, classifications technique and selected image data. LULC changes in a watershed region may influence water quality, surface runoff, groundwater discharge and transfer of pollutants etc (Wright et al., 2013). For that reason land use land cover information of a particular region is an important aspect for selection of site, planning, monitoring and management of water resources so that the changes in Land Use meet the growing demand for societal needs without hampering water quality. The LULC classification may be divided into many types of levels (Arveti et al., 2016). Table 1.5 shows the 3 levels of LULC classification. This level of categorization is not final, requiring the necessary information to expand or decrease the scale.

Table 1.5 LU/LC classification system

Level-I	Level-II	Level-III
Built-up land	Built-up land	
Agricultural land	Crop land	Rabi Kharif Rabi+Kharif
	Fallows Plantation	
Forest	Evergreen/semi-evergreen forest	
	Deciduous forest	Dry deciduous Moist deciduous
	Degraded or Scrub land	Scrub land Scrub land dense
	Forest blank Forest plantation Mangrove	
Wastelands	Salt affected land Waterlogged land Marshy/swampy land Gullied/ravinous land Land with or without scrub Sandy area (costal and desertic) Barren rock/stony waste/sheet rock area	
Water bodies	River/stream	Perennial Non-perennial
	Lake/reservoir/tank/canal	Small (as per area) Medium Large
Others	Sifting cultivation Grassland/grazing land Snow covered/Glacial area	

Source: Rao et al.,1991

1.2.6.3 GIS Mapping Approach

Conventional maps are prepared as hard copies on paper of certain sizes and scale. There was no chance of variety of scale and dimensions of the map. Nowadays the convenience of digital maps or geospatial databases can be dynamically maximized or reduced to change the map scale. The advancement of Remote Sensing and Geographical Information System (GIS) technique is the only way to fix this kind of difficulty. GIS is a computer system for data capturing, storing, data querying, analyzing and displaying the geo-spatial data. GIS can integrate and analyzes the different types of spatial data. GIS helps us to view, comprehend, query, interpret, and envisage data in a variety of ways that manifest the relationships, distribution patterns, trends, etc. in the form of digital maps, reports and graphical charts.

GIS can generate different types of maps in digital form depending on different types of data and spatial analysis (Curtarelli et al., 2015). GIS gives us opportunity to understand, interpret, view and visualize data in the different procedures that reveal relationships, trends and patterns in the form of maps, reports and in graphical forms. GIS tools help to understand and work out the problems looking at the data in a way that is quickly acceptable and easily shared to the end user. GIS technology can be integrated into any multiple user system frameworks.

The GIS has been used in different fields like surface water quality assessment (Kisku et al., 2017), aquaculture sector (Dutta et al., 2016), site suitability measure (Assefa et al., 2018), digital soil mapping and cropland suitability analysis (Forkuo and Nketia, 2011), groundwater quality assessment (Nas and Berktay, 2010; Jeihouni et al., 2014), health GIS (Yasobant et al., 2015), forest mapping etc.

Food and Agriculture Organization (FAO) of the United Nations Rome, 2013 published an essential guide to understanding the role of GIS analysis in the sustainable development and management of fisheries and aquaculture. Manjarrez et al (1995) compiled thirty numbers of thematic layers into fourteen environmental criteria in GIS platform to plan for an aquaculture venture and to reduce environmental damage and economic risks, the areas which are suitable for aquaculture and agriculture development were spatially defined. Kebede and associates (2015) analyzed overlay operation in GIS Software to produce suitability map and identifies and quantifies appropriate site for pond production. The analytical hierarchical process was used to analyze the importance of each parameter of soil quality, water quality and infrastructure facilities for development of aquaculture in a particular region. Researchers (Nayak et al., 2014 and Dutta et al., 2016) used the high resolution multi-temporal Google Earth images to recognize the changes of land use pattern happening due to disorganized expansion of brackish water fisheries along the coastal areas of Purba Medinipur district, West Bengal through different Remote sensing and GIS approaches. Different zone wise GIS maps are produced based on different aquatic parameters and available fish species as well as there is a clearly indicates of conservation concern to be addressed in urgent mode. Entire study region categorically divided into multiple zones for well managed and detail investigations. For collecting ground location data the Global Positioning System (GPS) device has been used (Kisku et al., 2017). Wagdy and associates (2015) used the Idrisi GIS software package to carry out the analysis and created the map. Multi-criteria evaluation methods within a GIS atmosphere can be carried out using other GIS software packages like ILWIS with Spatial Multiple Criteria Evaluation Tool and ArcGIS based Weighted Overlay Analysis, LUCIS (Land Use Conflict Identification Strategy) Model that have similar applications. The methodology described that it could also be adapted to be used in other GIS packages. The resulting map can act as a tool in helping decision makers visualize choices and evaluate suitable aquaculture areas alternatives.

Water quality parameters measurement and analysis are important technique for regular monitoring and to understand their characteristics and different environmental conditions. There is a lot of difficulty and impracticable to collect all water sample points of a large area and it is expensive too. For this conditions GIS is a most advanced tool and has great potential to solve these kinds of practical problems. Interpolation method in GIS environment is able to predicting the value of attributes at unsampled locations and this geo statistical analysis approach can be described as a set of techniques used to predict values of a variable distributed in space or time (Nijmeijer et al., Kushwaha et al). Kriging interpolation method is an approach to mapping the water quality parameters distribution for analyzing the dispersion patterns. Nagalakshmi and colleagues (2016) applied Kriging interpolation method for analysis of surface water quality properties like pH level, salinity, temperature, chlorophyll content and suspend sediment (SS) in water to carried evaluation investigation between different season basis in lagoon at Vedaranyam wetland.

To calculate the density of different phenomena in landscape many researchers has used different geo statistical techniques in spatial analysis module. There is always a numbers of question raised that what technique should be the most precise, what radius should be used etc. Different density measurement tools and techniques can calculate the density of input features within a neighborhood around each output raster cell. Strength of GIS-based density estimation method, the Kernel Density tool calculates the density of features in a neighborhood around those features. For both point and line features KD can be calculated. Possible uses of density tools may be settlement or urban growth, crimes for community planning, water body area change or exploring how roads or utility lines influence a wildlife habitat (Pro.arcgis, 2019). Bonnier and associates (2019) produced the heat maps with the help of Kernel Density Estimation tool which helps to visualize patterns of dispersal, nucleation and assessment of spatial shifts of land-use systems.

The growth trend and pattern analysis of any variables in GIS platform is an important aspect. The growth and sprawling of impounded waterbody have become significant concern throughout the world in the past few decades and it has economic, cultural and natural impacts on society. Entropy is an proficient method for comparing sprawl patterns (Sudhira et al., 2004., Jat et al., 2007., Yeh et al., 2001), therefore, the Shannon's entropy for each zones and time period should be calculated, and the degree of sprawl measured by the value of entropy which varies from 0 to logarithm of number of zones or time period (Chong, 2017).

$$\mathrm{E} = \sum_{i}^{n} PDEN_i * \log_{10}\left(\frac{1}{PDEN_i}\right) / \log_{10}\mathrm{n}$$

$$PDEN_i = DEN_i / \sum_{i}^{n} DEN_i$$

Where, PDENi is the density of the variable, n is the total no of zones, i is the existing zone being considered and PDNi is the probability or proportion of variables within zone i.

Researchers (Deka et al., 2011; Shenbagaraj et al., 2019; Punia, and Singh , 2012) used Shannon's Entropy approach to evaluate the trend of urban growth in North-East India, Chennai and Jaipur, respectively. The entropy theory also provides a suitable framework to analyze spatio-temporal variables like impounded water bodies, stream flows, urban growth, etc (Smulders, 1995; Cabral, 2013). The entropy value near to zero indicate the compactness of the structures and near the logarithm number of area is dispersed (Sudhira et al., 2004.; Sun et al., 2007).

Growth rate is the expansion of a variable that is time-dependent (Egghe and Rao, 1992). The Growth Rates can be calculated by using the various growth models like Geometrical Mean, Exponential, Logistic growth, Ware's model etc (Egghe and Rao, 1992; Snell, 1978). The changing rate of percentage between the period is calculated from the formula:

$$\mathrm{GR} = \frac{V_{pre} - V_{past}}{V_{past}}$$

$$\mathrm{PR} = \frac{V_{pre} - V_{past}}{V_{past}} * 100$$

Where, GR is growth rate, PR is percent rate, V_{pre} and V_{past} are present value and past Value. The article ‘Estimating the size of the Adult Population (2008)’ established the proportion of the population in their chapter 14 as:

$$\mathrm{Q} = \frac{m_i}{n_i}$$

Where, Q is proportion of the population, m_i is individuals of the day i and n_i is the numbers of individuals of the day i.

Some time growth rate can be calculated over the year. It can also be calculated on monthly or quarterly basis by Arithmetic Mean methods and Compounded Growth method (Dividend Growth Rate, 2020).

$$GR_{Am} = \frac{G_1 + G_2 + \ \dots \dots \ G_n}{\mathrm{n}}$$

$$GR_c = \left(\frac{D_n}{D_o}\right)^{\frac{1}{n}} - 1$$

Where, GR_{Am} GR_c are the Growth rate using Arithmetic Mean and Compounded Growth respectively, Gi is Dividend growth in i^{th} year and n is no. of periods, D_n is Final dividend, D_o is initial dividend.

Therefore, Remote Sensing and GIS have been utilized in the present research to complete the objectives.

1.3 Thesis Organization

The present thesis entitled "Characteristics and diversity of fish germplasm and water bodies in Purba Medinipur district, West Bengal using geospatial technology" is categorized into seven major chapters. There are seven chapters in the study which combined the thesis and helps to achieve the goals and objectives of this research. A brief overview is as follows:

Chapter 1:

This chapter explains the idea about the objectives of the present study, research questions, importance and demand of freshwater fish. It is also makes a statement about reviews of previous studies and available literature on history of aquaculture, freshwater fish, fish diversity, suitable site measuring through remote sensing - Geographic information system (GIS) technique.

Chapter 2:

The details about the study area are mainly described in this chapter. This chapter mainly describes about the geographical location, demographic character, transport network details, river and drainage pattern, geomorphology, soils, Land Use Land Cover, weather and climate, locations of important places etc. of the study area.

Chapter 3:

The data and materials used in this research their descriptions are presented in this chapter. The overall methods adopted in this study are briefly explained, along with field data collection and reference data in this chapter.

Chapter 4:

This chapter explains the detail process of aggregated impounded water bodies’ growth rate, patterns and density analysis. The entropy model, kernel based density model, class wise water distribution etc. techniques were adopted to achieve the goal. This chapter also describes how the concentration of water bodies is correlated with geomorphological units.

Chapter 5:

This chapter describes the status of fish diversity in the study area based on different fish farm and market surveys. The list of total fish species was classified and their Order, Family, common name, etc. has been reported in this chapter. The fish species and their International Union for Conservation of Nature (IUCN, Vers. 2020-1) red list status were listed in this chapter. Some species were also identified as a locally threatened category and listed.

Chapter 6:

This section describes the different environmental and socioeconomic parameters for the selection of suitable aquaculture sites in the area. This chapter also describes the SSFF and SSCFF models in terms of parameters and weights to achieve the distribution of suitable sites.

Chapter 7:

In this chapter, a summary of the study and an outline of the total study are made and the conclusion has been drawn. The future scope and limitations of this research has also been mentioned in this chapter.