Chapter 6
Site Suitability Analysis

Aquaculture and fish farming sector occupies an important role to grow the fastest food production and to meet the nutritional as well as protein requirement for the increasing population of our country. It is recognized as a strong income and employment generator and a source of cheap and nutritious food as well as being a foreign exchange earner. For overall development of our society the production of fish needs to be enhanced.

Therefore, to enhance the fish growth and production the selections of site is an important factor. To run a successful aquatic farm, a suitable site needs to be identified and procured to ensure gain and reduce environmental pollution. The selection of suitable sites effect both success and sustainability and it can be an important factor for production rates, mortality factor and environmental pollution etc (Amangabara et al., 2017).

The potential and most suitable site were analyzed based on two analytical frame work

A. Site Suitability for Fish Farming (SSFF)

B. Site Suitability for Commercial Fish Farming (SSCFF)

It is observed from the previous study that many methods involved in the decision-making process like survey based analysis, check list method, ranking based method etc (Rikalovic et al., 2014; Assefa and Abebe, 2018). New trends in information technology, remote sensing and GIS is the necessary and most advanced technology for spatial distribution, mapping and planning for fish farming development (Richard and Ogba, 2016).

To carry out the overall objectives for SSFF and SSCFF model, multi criteria GIS techniques are adopted (James and Jose, 2007). A brief sketch of used criteria and flowchart are described below (Figure 6.1).

The figure 6.1 describes the general idea about the selected parameters and methodological flow. At first, all parameters are converted into GIS environment with the help of ArcGIS 10.5 software package. The spatial expansion model of ArcGIS 10.5 was utilized for analysis and to achieve the aim. The suitability parameters were selected based on three criteria, i.e. (a) physicochemical conditions, (b) weather and environment and (c) establishment and profitability. The distribution of the geospatial data (primary and secondary) such as water quality (temperature, pH, dissolved oxygen, TDS), soil (PH, texture) precipitation and population of fisherman family were first substitute into point base spatial interpolation operation.

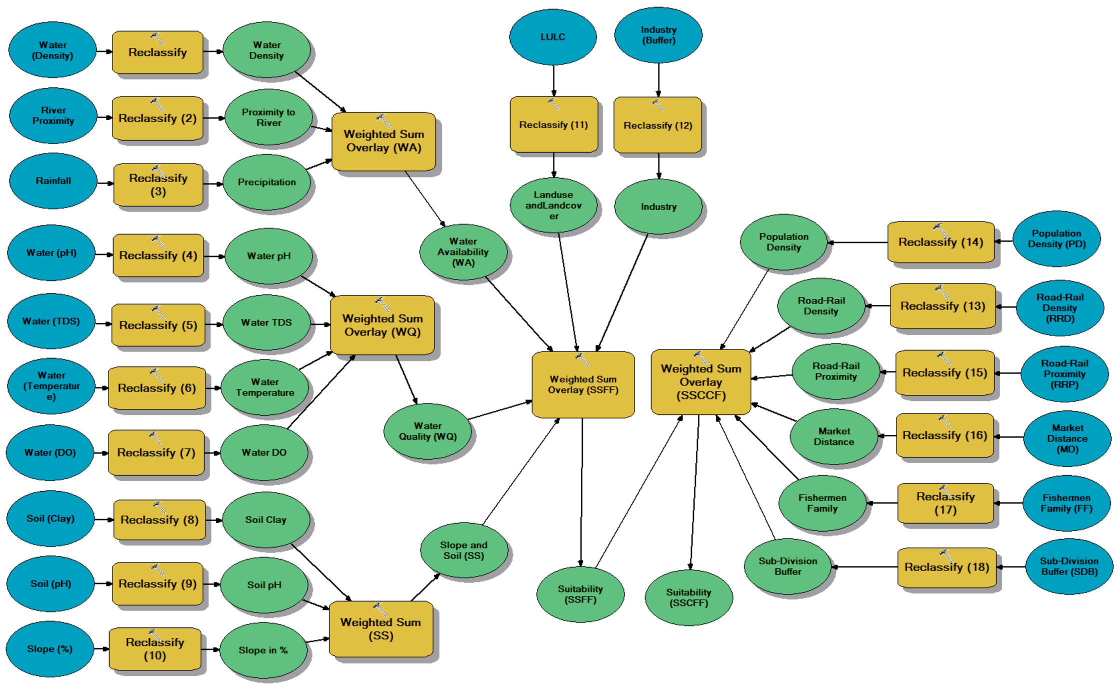

Figure 6.1 Methodological model of SSFF & SSCFF

The spatial analysis and proximity analysis technique has been utilized to retrieve the Density (water body, population etc.) and proximity of the perennial river, road-rail, market, industries, sub division head quarter. On the other hand, the LULC and slope (%) has been generated from Sentanel-2B and ASTER DEM data respectively. All the generated results were registered on a unit meter containing the WGS 1984 UTM Zone 45North reference system. Prior to generation of the LULC, the data was ortho-rectified to achieve the geometric scale correction with the help of ERDAS imagine software package. Therefore, the on-screen digitization techniques has been implemented to extract the LULC information through the ARC GIS software package. Finally, weightage overlay analysis process has been used to evaluate and mapped the distribution of final suitability status. The details about the suitability parameters, classification criteria analysis and technique are described below.

6.1 Site Suitability for Fish Farming (SSFF)

The weightage based SSFF model was developed to find out the proper site included various numbers of parameters which are classified into a chain of sub-models. The waterbody density (WD), proximity to river (km), precipitations were grouped into a sub-model, denominated water availability (WA) and water pH, DO (mg/l), Temperature (˚C) and TDS were described as a sub-model of water quality (WQ). Some other parameters were categorized into sub-models according to their collective characteristics like slope & soil (SS) and others (OT). Each parameters were given a score 3, 2 and 1 according to Suitable, Moderately suitable and Unsuitable.

6.1.1 Water Availability (WA)

6.1.1.1 Water body Density (WD)

The water body density is an important indicator and factor for thorough site selection for fish farming due to its adequate source of availability. To delineate the detail about impounded water body the Sentinel-2B (10m x 10m) data of European Space Agency (ESA) and Google Earth image data (2018) were used.

A grid based density of water body area is measured through GIS technique. A 2 km × 2 km grid for the entire study area was generated, comprised of 1092 grids. The existing water areas of the corresponding grid were assigned into each grid by a unique Id. After that the density of the water was calculated in respect to its corresponding grid area (40000 m^2 etc.). The distribution of water body density has depicted in figure 6.3a. The distributions of WD were classified into three (high, medium and low density) classes (Table 6.1).

6.1.1.2 Proximity to drainage

The proximity to drainage is another parameter of sub-model WA. This parameter described the contiguity to the existence and water balance of aquatic resources. The major rivers (Rupnarayan, Keleghai, Haldi etc.) of the district were digitally delineated based on Sentinel-2B (2018) satellite data.

After that proximity to water were calculated in kilometer (km.) unit using the analysis module of Arc GIS 10.5 and reclassified into three classes (based on criteria and scale) i.e. suitable (< 1 km.), moderately suitable (1-2.5 km.) and unsuitable (> 2.5 km.) (Table 6.1). The distribution of major perennial rivers and its proximity is illustrated in figure 6.3b.

6.1.1.3 Precipitations

Sufficient water sources are more important parameter for establishing the aquatic fish farm. The availability of water in ponds and perennial rivers are mainly depending on rainfall. Therefore, precipitations (rainfall) are an essential factor for SSFF. The annual rainfall more than of 1200 mm is generally suitable for fish farming (Kapetsky J. M. 1994; Assefa and Abebe, 2018). In this study area the annual rain fall is sufficient and going beyond the desire amount due to tropical monsoon region. The annual rainfall (mm) has been considered and categorized into three levels (Suitable: >1900 mm, Moderate suitable: 1800 – 1900 mm and Unsuitable: < 1800 mm) (Table 6.1 and figure 6.3c).

Table 6.1 Classification criteria and suitability rating of sub-model, WA

Parameters	Classification criteria and scale			Theme weighted
	Suitable (wi:3)	Moderate suitable (wi:2)	Unsuitable (wi:1)	
Waterbody Density (WD)	High	Medium	Low	0.35
Proximity to Drainage (km)	< 1	1 - 2.5	> 2.5	0.35
Precipitation	> 1900	1800 - 1900	< 1800	0.30

The weighted value of sub model water availability is given according to their importance. The water Density and Proximity to river is given the more importance 0.35 each comparing to the precipitation parameter is given the weight of 0.30 due to availability of sufficient amount of annual rainfall in all over the district.

6.1.2 Water Quality (WQ)

The standard water quality of any aquaculture farm is required and it's an important factor (Coldebella et al., 2017). The physical and chemical properties of water are a key factor of water quality. The organic and inorganic pollutants of water have the adverse effect and it's directly effects the yield of fish of the water bodies (Ezeanya et al., 2015;

Summerfelt et al., 1995). Different physiochemical properties of water and their standard ranges will directly involve the health of water (Nas and Berktay, 2010). Therefore the estimating of physical and chemical properties should be considered.

In this context the water samples were collected and studied the physiochemical properties throughout the district. Some field photographs of water sample collection are presented in Annexure III**.** Water samples were collected from each and every block of the entire district in small bottle and labeled with identification name, date and recorded the latitude and longitude values by GPS of each sampling points. Before the collection of samples the containers are washed and rinsed with same water that is collecting from sampling water body. All are kept in a cool and safe place till the samples were measured and analyzed in water analyzer kit. (WQ_aquaculture)

The pH, DO of water samples were measured with the help of Systronics water analyzer 371 kit. To calibrate the water analyzer kit for pH measurement the two kind of buffer solution was prepared to standardize the device, (a) Solution of 100 ml double distilled water with 4 pH buffer capsules and (b) Solution of 100 ml double distilled water with 7 pH buffer capsules. To estimate the DO, the water analyzer kit also calibrated through solution of 7.5 gm kcl in 100 ml distilled water with Agcl crystal. The TDS and temperature of water sample were measured through portable Pushcart Tds-3 digital meter.

6.1.2.1 pH

In water quality parameters pH is an important factor and is influenced by the concentration of carbon dioxide (Boyd, 1979). Basically pH indicates the acid base balance of the water. The suitable range for aquaculture is normally between pH 6.5 to 9. The range between 7 to 8.5 is perfect range for biological productivity. The ideal range for pH in fish culture should have 6.5 to 9 (Bhatnagar and Devi, 2013). Fish cannot survive the pH range from 4.0 to 6.5 and 9.0 to 11.0, become stressed due to hyper and hypo level of pH respectively. Deaths at a pH level < 4.0 or > 11.0 are almost certain (Ekubo and Abowei, 2011). Different organic matter like cow dung, poultry droppings and quicklime (Cao) is generally used to rectify the pH level of water.

Therefore the pH has been considered as a water quality parameter for suitable site analysis.

The pH values has been categorized into three levels (Suitable: 6.5 - 8.0, Moderately suitable: 4.5 - 6.4 & 8.0 - 9.2 and Unsuitable: <4.8 and >9.2) (Table 6.2 and figure 6.4a). The classification scale of pH of sub model WQ is given according to their magnitude. The 3 is given to suitable pH comparing to the moderately suitable (2) and unsuitable (1).

6.1.2.2 DO

Dissolve Oxygen also plays a vital role for maintaining the levels of oxygen in water body as well as in fish farming. The major source of oxygen in water is coming from the atmospheric air and photosynthetic planktons. Fish growth, survival power, behavior and distributions are also directly depends on DO. (Solis, 1988) The Dissolved Oxygen that is present between 3.0-5.0 ppm in ponds is unproductive and for typical or good production it should be greater than 5.0 ppm. (Banerjea, 1967)

The fish become death with DO ranging bellow 1 mg/l while fish survive (grow slowly and will be sluggish) with 1 to 5 mg/l and desired with more than 5 mg/l. So, the DO plays a significant role in fish productivity, considered as a water quality parameter for fish pond management. DO have been categorized into suitable (6 – 7 mg/l), moderately suitable (3 - 6 mg/l) and unsuitable ($<$ 3 mg/l), scaled in to 3, 2, and 1 respectively (Table 6.2 and figure 6.4b.)

6.1.2.3 Temperature

Temperature influences the different chemical and biological processes in the water. Growth, oxygen demand, food requirements and food conversion efficiency has great influential impact on temperature. As temperature increases, oxygen and food requirement also increases with faster growth rate. The range of between 27.6^0C to 30^0C is most favorable for yield in aquaculture (FAO, (2006). Temperature between 28^0-32^0C is much endurable for tropical major carps (Bhatnagar et al., 2013). Oxygen concentration is generally being low due to solubility of oxygen decreases as with increasing temperature in the time of summer.

The temperature values has been categorized into three levels (Suitable: 25 - 30, moderately suitable: 14 – 24.9 and Unsuitable: <14 & >30) (Table 6.2 and figure 6.4d). The total range of temperature are classified and scaled. Suitable range has given the highest value of 3 and 2 & 1 given as a moderately suitable and unsuitable respectively.

6.1.2.4 TDS

Total Dissolved Solid (TDS) is a quantifiable factor of inorganic salts, organic matter and other dissolved materials in water (U.S. Environmental Protection Agency, 1986). An invariable level of minerals in the water is required for aquatic life. TDS contain minerals and organic molecules that are beneficial for nutrients and contaminants such as toxic metals and organic pollutants. Changes in the quantity of dissolved solids can be disastrous because the concentration of total dissolved solids impacts the flow of water in and out of an organism’s cells. Density that is too high or too low can lead to the death of many fish. Many freshwater fish requires a significantly lower level but a level of 400 ppm or less is suggested (Aquariums and Aquaculture, 2019). Therefore TDS is also an important parameter of water that plays a vital role in fish farming and fish growth.

TDS values have been categorized into suitable (<400), moderately suitable (401-500), unsuitable (>500) and scaled them according to their importance into 3, 2, and 1 respectively (Table 6.2 and figure 6.4c.)

Table 6.2 Classification criteria and suitability rating of sub-model, WQ

Parameters	**Classification criteria and scale**			**weighted**
	Suitable (wi:3)	**Moderately suitable (wi:2)**	**Unsuitable (wi:1)**	
pH	6.5 - 8.0	4.5 - 6.4 & 8.0 - 9.2	<4.8 & >9.2	0.30
DO (mg/l)	6 - 7	3 - 6	<3	0.30
Temperature Max. (˚C)	25 - 30	14 - 24.9	<14 & >30	0.20
TDS (ppm)	< 400	401 - 500	>500	0.20

The total weighted is assign between 0 to 1 values for individual water quality parameter. According to their importance based on aquaculture the weight 0.30 has been given to the each parameter of pH and dissolve oxygen. Further, weight 0.20 has been given to temperature and TDS.

6.1.3 Slope - Soil

Soil quality is an important key factor in aquaculture as most ponds are built from and in soil. Soil is the most influential factor for the water which has many dissolved and suspended materials in them. Controlling factors of fish pond productivity like soil pH, salinity, stability of bottom surface which are beneficial for the plant nutrients as well as the food cycle of the fish. With neutral pH where the soil is deep, water infiltration is low, mineralization of micro biotic matter evolves, nutrients which are absorbed and released slowly over a long period of time where a planned site could be constructed for fish ponds. Pure clay has a property of high absorption (Panda et al., 2014) which comes under too heavy textured soils act as a wall for nutrients like phosphorus can’t be in direct contact with the water & these soils also developed deep cracks which results into seepage loss of water.

6.1.3.1 Slope

Slope is the angular difference between the two geographical locations. The flow of the water direction can influence by the slope of the landscape. In case of aquaculture site selection as well as enhancing the pond production system it would not be favorable to construct a pond with in a steep slope landscape. The water depths would be varying if it is constructed in a steep slope site. Side by side it will be very less chance to available of surface water with increasing slope. Therefore, the slope data considered as an important factor in site suitability analysis.

The slope has been generated from the SRTM data using Arc Map 3D analyst tool and calculated in percentage (%) unit. The detail of slope generation procedure is mentioning in a model (Figure. 6.2) (Panda et al., 2014).

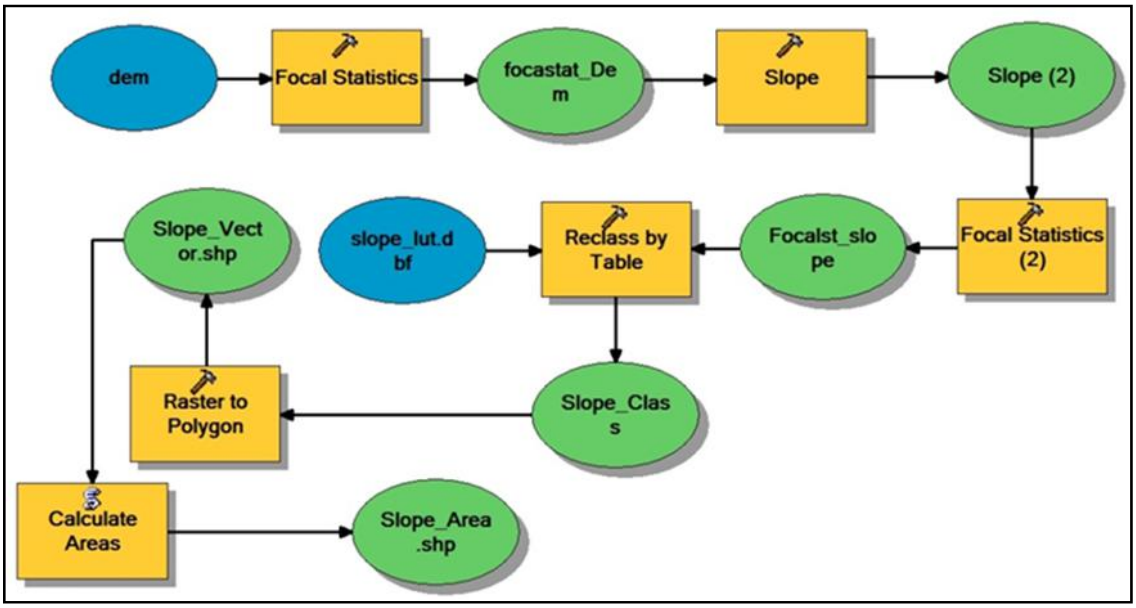

Figure 6.2 Model base workflow diagram of slope generation (Source: Panda et al., 2014)

At first the smoothening techniques was implied to smoothening the DEM data using a circular neighborhood with 3 map unit or cell. After getting the smooth DEM data the slope has been generated and further smoothening technique applied. The vectorization process was also applied over smooth slope data. The generalization method has been processed on vector data to minimize the local error and for better visualization.

Due to the study area has fallen into a plain surface region and less variation of topographic slope, the values have been categorized into suitable (<3), moderately suitable (3-8), unsuitable (> 8) and given the values according to their importance 3, 2, and 1 respectively (Kebede et al., 2015) (Table 6.3 and figure 6.3d.)

6.1.3.2 Soil pH

In case of pond bottom soil the pH also a crucial factor. The soil pH value can indicate the characteristics of soil whether the soil is acidic or not. pH value with 7 is the neutral condition of soil, when its neither acidic nor basic. So, the value less than 7 is basically acidic condition and above the level of 7 recognized as an alkaline. The finest level of pH in case pond bottom soil is considered to be about neutral (Boyd, 1995). At pH level 7 the availability of phosphorous is occurs to the maximum level. Soil microorganisms, soil bacteria are function best at pH level 7 to 8 (Boyd et al., 2002).

So here the soil pH has been considered as an imperative factor to evaluate suitable site analysis.

The soil pH values has been categorized into three levels (Suitable: 5.0 - 8.0, moderately suitable: 4.0 – 4.9 and Unsuitable: <4.0) (Table 6.3 and figure 6.3e). The categorizing scale of pH of sub model slope and soil is given according to their importance. The 3 is given for highest importance as suitable pH and the moderately suitable (2) and unsuitable (1) respectively.

6.1.3.3 Soil texture (%)

Soil texture related to the distribution of particle-size or diameter in the soil. A soil texture name can be categorized based on percentages of clays, silt, and sand (Hossain and Das 2010). More clay content in respect to other components of soil of aquatic pond is suitable for fresh water aquaculture (Nayak et al., 2014).

The clay content with less than 20% is unsuitable. On the other hand, the clay content with more than 50% and 20 - 49% preferable to suitable and moderately suitable, respectively (Assefa and Abebe, 2018). The interpretation of suitability of texture classes were classified on the basis of criteria and scale from 3 (Suitable) to 1 (Unsuitable), presented in Table 6.3.

Table 6.3 Classification criteria and suitability rating of sub-model, Slope and Soil

Parameters	**Classification criteria and scale**			**weighted**
	Suitable (wi:3)	**Moderately suitable (wi:2)**	**Unsuitable (wi:1)**	
Slope (%)	<3	3-8	>8	0.20
Soil pH	5 - 8	4 - 4.9	< 4	0.35
Soil texture (% clay)	>50 %	20 - 49 %	< 20 %	0.45

The weighted of individual parameter of sub-model ‘slope - soil’ assign by 0 to 1 based on their importance. The weight of 0.20, 0.35 and 0.45 were ascertained into slope, soil pH and soil texture respectively.

6.1.4 Land use Types (LT) and Proximity to Industries (PI)

The others influences like land use types and the location of industries were taken into account for suitability analysis model. The highest priority has been given to water body class (3) and the second priority is given to crop land or agricultural field for the suitable site selection and the others classes have been grouped and chosen for less priority (Table 6.4). The industries locations have also been taken into consideration through proximity analysis and >2 km distance from the proposed site has given the highest priority. The location of aquaculture site near the industrial area of <1 km was taken as an unsuitable for fish farm (Table 6.4).

Table 6.4 Classification criteria and suitability rating of sub-model, LT and PI

Parameters	**Classification criteria and scale**		
	Suitable (wi:3)	**Moderately suitable (wi:2)**	**Unsuitable (wi:1)**
Land use Types	Water body	Crope/agricultural land	Others
Proximity to Industries (.km)	> 2	1 - 2	< 1

To appraise the theme weight of each parameter of each sub-model were reclassified on to a common scale and classification criteria of suitable, moderately suitable and unsuitable, re-classed by 3, 2 and 1 in that order. Further, the level of suitability sub-model of SSFF and their theme weight are given based on literature studies, expert's opinion and biological study of the fish species. Theme weight of each sub-model of SSFF was presented in table 6.5.

Table 6.5 Theme weighted of each sub-model, SSFF

Water Availability (WA)	Water quality (WQ)	Slope - Soil	Land use Types	Proximity to Industries (km)
0.3	0.25	0.2	0.2	0.05

6.2 Site Suitability for Commercial Fish Farming (SSCFF)

The SSCFF model was also developed included different parameters that are economy based, to access the location of sites which are economically or commercially suitable. The parameters like population density (km^2), road and railway density (km^2), road proximity (in km.), proximity to market (in km.), population of fish farmer, proximity to SD head quarters (in km.) are considered to develop the model including with SSFF model. Each parameter were classified into three classes and given the scale (3-1) according to their importance.

6.2.1 Population density (km^2)

The rising fish demand is associated with the increasing rate of population (Manjarrez and Ross, 1995). To fulfill the deficit or surplus as mentioned in chapter 1, the SSCFF model plays a significant and desirable role. So, the density of population has been preferred as a parameter in this study.

The density of population in this study area are classified into three classes and highly populated area chosen as a highest priority (3) and the others classes following as a moderate (2) and unsuitable (1).

6.2.2 Road and railway density (km^2)

Road and railway density is also an essential factor for ascertaining the site of economy based aquaculture cause of its accessibility. The site should be in the surrounding area of transportation routes or it should be constructed where the accessibility of road can be constructed economically (Kapetsky, 1994).

The road and railways network were delineated from the Sentinel-2B (10m x 10m) data of European Space Agency (ESA) and Google Earth image data (2018). The density (D_{RR}) of the feature (Rail and Road) has been generated per unit area. The L represents the length of each road-rail, falls within the unit area (A_c) and n is the number of rail-road with in the unit area. Here unit area is used as a circular neighborhood (area of circle) of the corresponding location or pixel.

$$D_{RR} = \left(\sum_{n=1}^{n} L_1 + L_2 + \cdots .. L_n \right) / A_c$$

The road-rail density was calculated by the ratio of their total length within the circle to the area of corresponding circle. The road-rail densities of the area were classified into three level of scale, i.e. highly dense area chosen as a highest priority (3) and rest of the area classified into moderate density (2) and low density (unsuitable: 1).

6.2.3 Road proximity (in km)

Road proximity analysis is also needed to know the actual scenario of the local area where the site should be constructed. The distance from the important road to the sites is a factor to its accessibility and as well as communication purposes (Kapetsky, 1994). So, the proximity of road was taken as a parameter and evaluates it to measure the suitable site for economy based fish farm.

The proximity of rail-road network describes the connectivity to the local market with aquatic resources. Therefore, the railway, NH, SH, district road and other major road network were preferred for proximity analysis. The Arc GIS 10.5 analysis tool was used to delineate the proximity zone, have divided into three level of scale. These zones were categorized based on distance (.km), < 7 km. for suitable (Scale: 3), 7 to 14 km. for moderately suitable (Scale: 2) and > 14 for unsuitable (Scale: 1).

6.2.4 Proximity to market (in km)

A significant assessment of potential fish market availability nearby the aquaculture site is an important factor for the feasibility of aquaculture site construction. For development of commercial fish production, location of market is one the most key factor (Manjarrez and Ross, 1995). Here the proximity of market was performed to know the actual accessibility or distance to project an aquaculture site. Minimum proximity of markets is easy to accessible for the small scale fishermen.

The <3 km. distances from the market location were given foremost priority (Classification scale: 3). The remote market locations from the project areas of more than 5 km. were taken as a less priority and ranked 1 (Table 6.4).

6.2.5 Population of fish farmer

The large numbers of fishing folk population are engaged in fishing and similar activities because the fisheries contribute to food security and direct employment. So, here the population size of fishing folk community has been taken into account as a crucial factor to access the site selection measure. The fishermen residents are direct or indirectly influenced the construction of fish farm and also in fish economy.

Particulars of fisheries in the block data from the district statistical handbook of Purba Medinipur (Department of Statistics & Programme Implementation, West Bengal) were taken as a reference of this study. The > 5100 persons who are engaged in fisheries profession have given the highest suitable scale 3. 4500 – 5100 and < 4500 persons are engaged in this profession were given as 2 and 1 respectively (Table 6.4).

6.2.6 Proximity to SD capitals (in km)

There is also a considerable role of sub-division capital as well as sub-division capital markets for fish economy. So, the distance from sub-division capital market is an issue as of its huge demand and supply of fish (Meaden and Manjarrez, 2013; Aswathy et al., 2011). The remote areas from sub-division capital region of the land were unsuitable due to its limited access to the sub-division market center for the improvement of fish farming in the study area.

The radial distances of < 5 km. from the SD capital locations were given maximum priority of suitability scale 3. Similarly, the radial distances of > 7 km. and 5-7 km. were given as the priority class 1 and 2 in that order (Table 6.4).

The weight of the theme of each parameter was reclassified with a regular scale of 3 (suitable), 2 (moderate suitable) and 1 (unsuitable). Further, the suitability of the SSCFF is assessed based on the level of theme weight according to their importance based on previous studies and expert opinion. The weights of the themes in each parameter of the SSCFF were described in Table 6.6.

Table 6.6 Theme weighted of each sub-model, SSCFF

Parameters	**Classification criteria and scale**			**Theme weighted**
	Suitable (wi:3)	**Moderate suitable (wi:2)**	**Unsuitable (wi:1)**	
SSFF	High	Medium	Low	0.22
Population density (km^2)	High	Medium	Low	0.12
Road – rail density (km^2)	High	Medium	Low	0.17
Road proximity (km.)	< 7	7 - 15	> 15	0.12
Proximity to market (km.)	3	3.1 - 5	> 5	0.17
Population of fish farmer	> 5100	4500 - 5100	< 4500	0.12
Proximity to SD capitals (km.)	<5	5 - 7	>7	0.8

6.3 Result and Discussion

The overall outcomes are separated into two sections: Site Suitability for Fish Farming and Site Suitability for Commercial Fish Farming. The first sections discuss about the results of the suitable condition of native fish farm, as well as the suitable site of aquaculture. Another part discusses about the results of economic sensitivity and distribution of suitable site.

6.3.1 SSFF

Site Suitability for Fish Farming reveals the suitable fish living environment condition and also selecting the suitable site for fish farming. Based on the surveyed data, different parameters were used to build a model for this suitable site selection process. The water density data is used due to its sufficient source of water. The availability of water of aquacultures is dependent on rainfall and perennial river. The result shows that in Moyna, Nandakumar, Contai-II and in some parts of Tamluk, southern part of khejuri-I, Ramnagar-II, Contai-I, eastern part of Ramnagar-I blocks is highly concentrated of waterbody (Figure 6.3a). Total distribution of waterbody density is classified into three level of scale, presented in Figure 6.5a. Proximity to drainage was also calculated in kilometer (km.) and categorized into three classes depicted in Figure 6.3b and 6.5b. The yearly precipitations of the present study are ranging from 1710 to 1901 mm (Figure 6.3c). From the Figure 6.5c it is observed that mainly Egra-I and II; Ramnagar-I and II; Contai I, II and III; and Patashpur-II blocks are fallen in high precipitation zone and rest of the areas are observed as less amount of annual rainfall as compared to mentioned blocks.

The output of slope has been calculated in percent (% increase) for better perceptive. As the percent of slope calculated through rising (Y) divided by the run (X) and multiplied with 100, the result of this present study ranging from 0 to 178 % (Figure 6.3d). Slope has been categorized into three levels of suitability classes depicted in Figure 6.5d. The entire district is on flood plains of the rivers of Hooghli, Haldi and Rupnarayan. A high amount of clay content dominates the soil texture in this region (Table 6.7). Maximum area of the district dominated by more than 50% of clay content other than Ramnagar-I, Contai-II, Mahisadal, Sutahata, Haldia, Panskura blocks etc. The detail about soil pH and texture presented in Table 6.7 and Figure 6.3e and f. As the soil pH ranges between 5 to 7 pH scale, entire district is comes under in a suitable category (Figure 6.5e). Figure 6.5f presented the three levels of suitability classes of soil texture.

Table 6.7 Block wise average soil properties of Purba Medinipur district

Block	pH	Texture	Clay (%)
Tamluk	5.80	Clay	50
Sahid Matangini	6.30	Clay	55
Panskura -I	5.90	Silty Loam	5
Panskura -II	6.20	Clay Loam	30
Moyna	5.80	Clay	64
Nandakumar	6.10	Clay	89
Nandigram - III	5.90	Clay	86
Mahisadal	6.36	Clay Loam	38
Nandigram - I	6.10	Clay	60
Nandigram - II	6.00	Clay	92
Sutahata	6.00	Clay Loam	11
Haldia	6.52	Clay Loam	21
Potashpur -I	6.60	Clay	85

Block	pH	Texture	Clay (%)
Potashpur -II	6.40	Clay	80
Khejuri - I	6.46	Clay	70
Khejuri - II	5.83	Clay	65
Bhagawanpur - I	5.02	Clay	85
Bhagawanpur - II	5.68	Clay Loam	51
Ramnagar -I	6.72	Loamy Sand	25
Ramnagar -II	5.90	Loamy Sand	60
Egra - I	6.50	Clay	68
Egra - II	6.40	Silty Clay	51
Contai – I	6.17	Loamy Sand	55
Contai – II	6.90	Silty Clay	44
Contai – III	5.95	Silty Clay	44

Source: Laboratory Analysis, Abas, Paschlm Medinipur, 2004-06
Soil Survey Report of State Soil Survey, 2003-05

There are four water quality parameters DO, temperature, pH and TDS are analyzed as a sub model of water quality (WQ), presented in Table 6.8 and Annexure I. The survey data shows that the water quality parameters of temperature ranging from 22.80 ^{o}C to 35.20 ^{o}C, pH ranging from 6.29 to 9.55 and TDS ranging from 68 mg/l to 1335 mg/l. DO vary from 2.87 mg/l to 8.80 mg/l are within the acceptable range which is favorable for construct fish farm and also enhancing the fish yields (Table 6.8). The spatial distribution of different water quality parameters has been presented in Figure 6.4a, b, c and d. The three level classification scale of water quality parameters are also presented in Figure 6.6a, b, c and d.

Table 6.8 Statistical data of average water quality, Purba Medinipur district

WQ parameter	Temperature (^{o}C)	pH	DO (mg/l)	TDS (mg/l)
Min	22.80	6.29	2.87	68
Max	35.20	9.55	8.80	1335
Average	30.57	7.47	5.83	405.09

LULC of the district was delineated into five major classes like agricultural land, build up (mixed settlement), water body, wasteland and forest. The LULC map of the study area is prepared, showing in Figure 6.4e and three level suitability classes are also presented in Figure 6.6e. The proximity to industries was also calculated i.e. < 1 km., 1-2 km., > 2 km. and categorized into three classes 1, 2 and 3 respectively, depicted in Figure 6.4f and 6.6f.

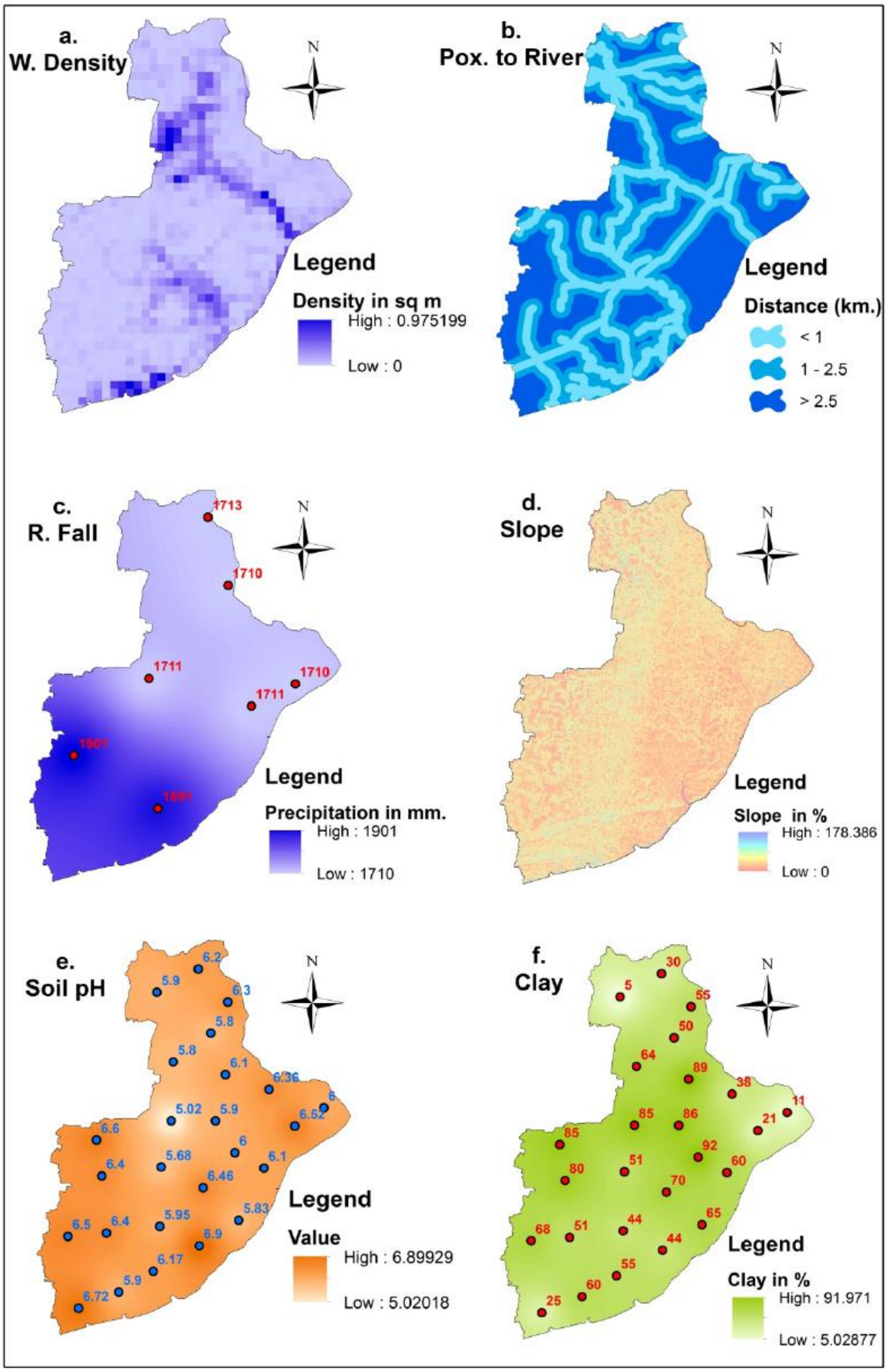

Figure 6.3 Suitability parameters map for (a) water density, (b) proximity to drainage, (c) precipitation (rainfall), (d) slope, (e) soil pH and (f) soil texture (% of clay)

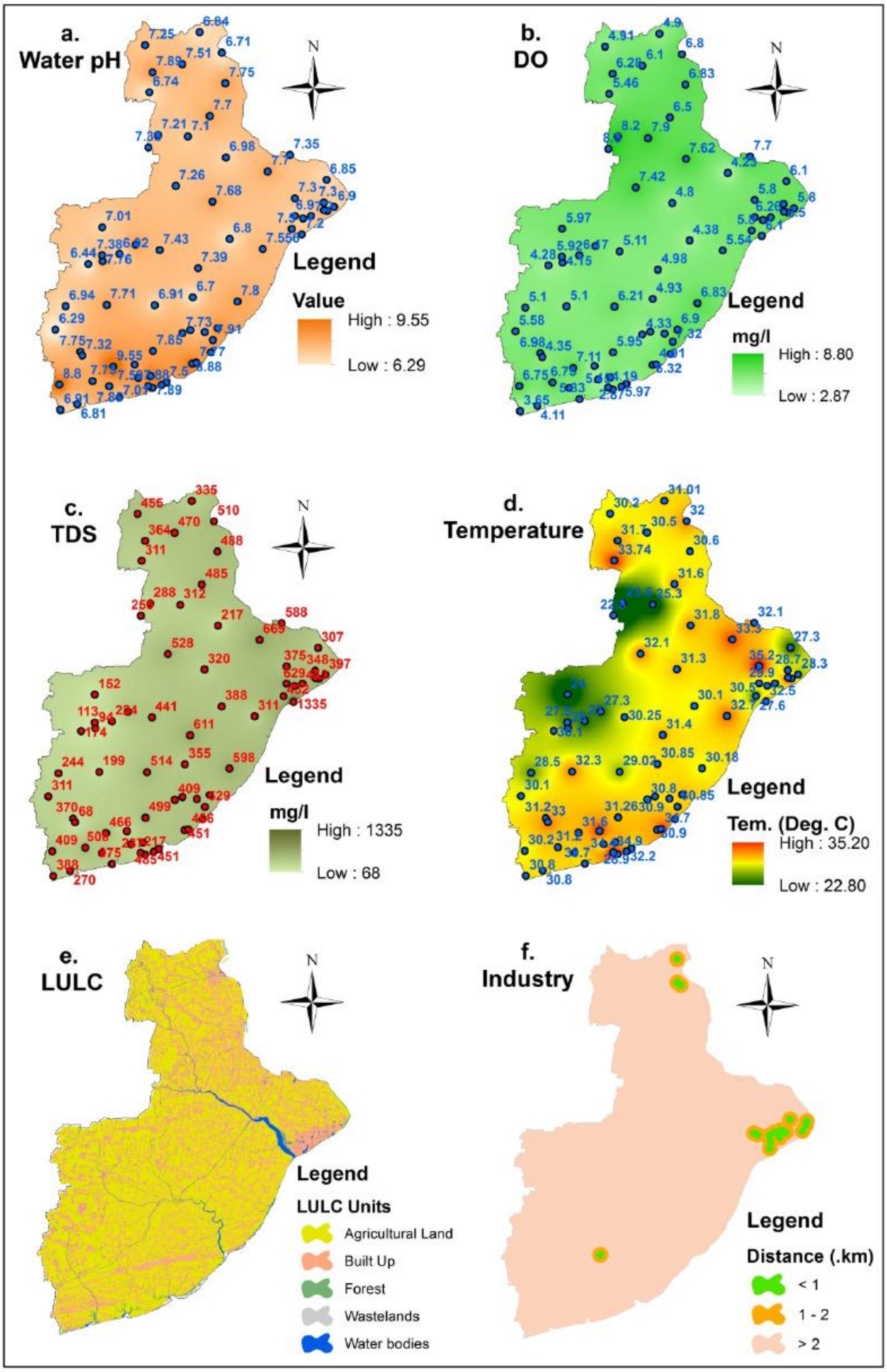

Figure 6.4 Suitability parameters map for (a) water pH, (b) water DO, (c) TDS, (d) water temperature, (e) LULC and (f) proximity to industry

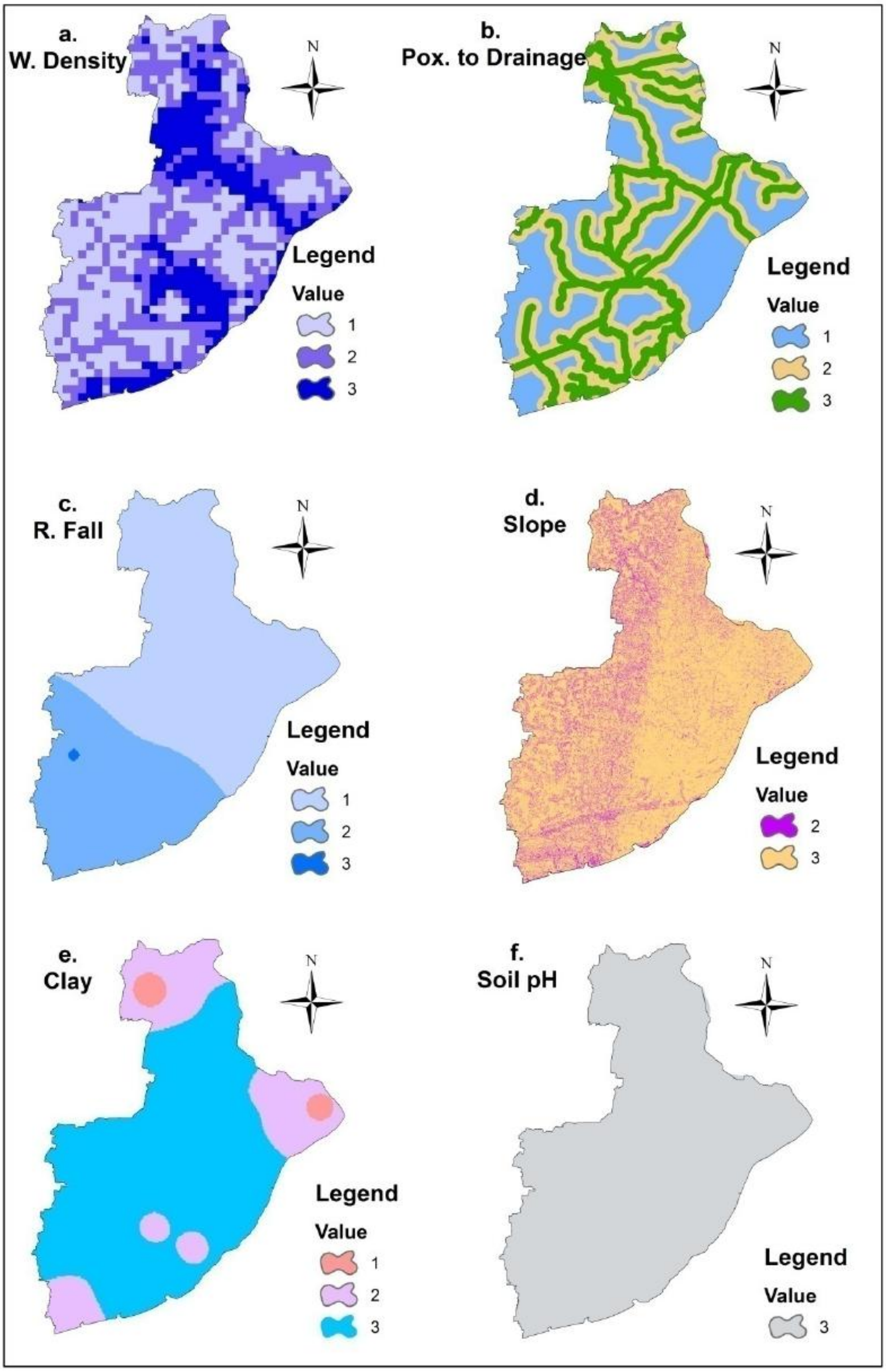

Figure 6.5 Suitability scale for (a) water density, (b) proximity to drainage, (c) precipitation (rainfall), (d) slope, (e) soil texture (% of clay) and (f) soil pH

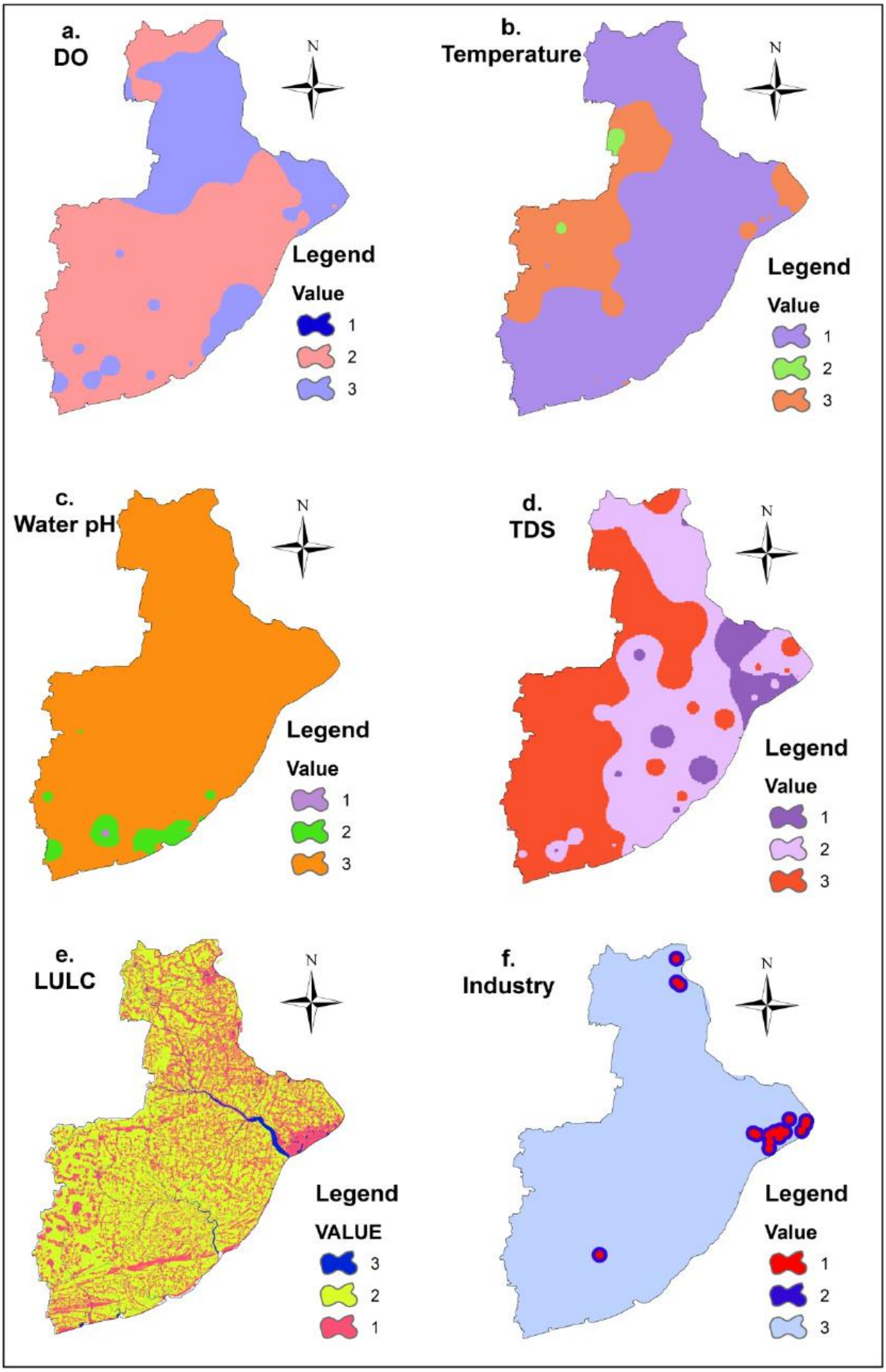

Figure 6.6 Suitability scale for (a) water DO, (b) water temperature, (c) water pH, (d) water TDS, (e) LULC and (f) proximity to industry

6.3.2 SSCFF

According to socio-economic and infrastructural condition the population density, road-railway density, proximity to road, market and SD capitals, population of fish farmers are mainly associated to low expenditure behavior, adequate production experience and a short distance to travel from the fish farm.

The accessibility of transportation facilities, including major roads and railways are significant for local connectivity with allied fish farms and markets. The proximity to road-railway were calculated i.e. < 7 km., 7-15 km., > 15 km. (Figure 6.7b) and categorized into three classes 3, 2 and 1 respectively (Figure 6.8b). Similarly, the proximity to market and SD capitals were calculated and categorized into three level of suitability class, presented in figure (Figure 6.7d, 6.7f and Figure 6.8d, 6.8f). On the other hand, population density, distribution of fish farmer population and road-rail densities (Figure 6.7a, 6.7c and 6.7e) were categorized in favor of economy based importance of the entire district (Figure 6.8a, 6.8c and 6.8e). Higher population density has been observed at northern part (Panskura, Tamluk, Haldia, Mahisadal, Nandakumar, Moyna etc, blocks), while higher fish farmer population has been observed at western part (Moyna, Nandakumar, Bhagabanpur etc. blocks) of the study area (Figure 6.7a and 6.7c). Similarly, the higher concentration of road-railways densities has also been observed in the northern part of the district (Figure 6.7c).

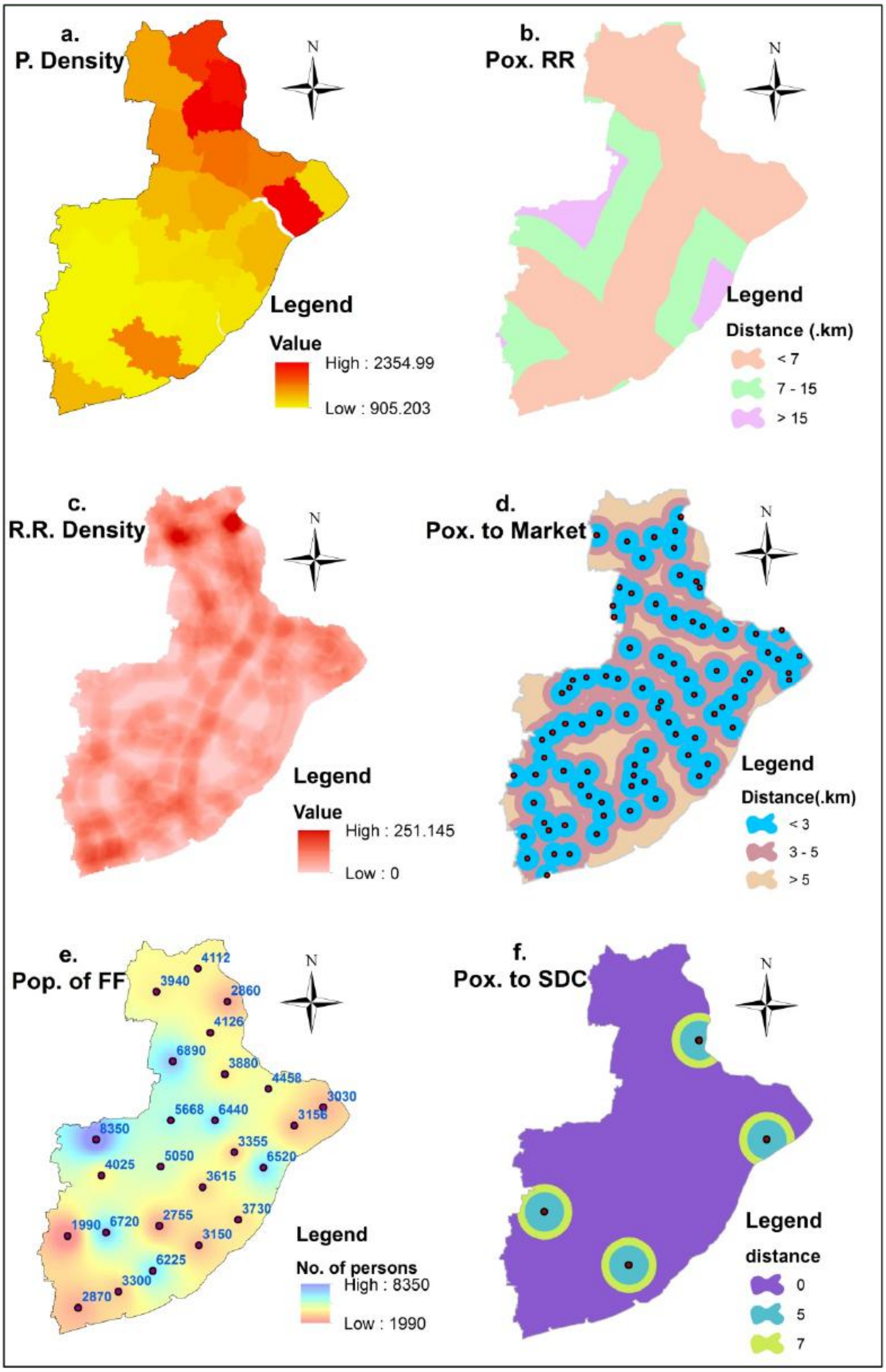

Figure 6.7 Suitability map for (a) population density, (b) proximity to road, (c) road-rail density, (d) proximity to market, (e) population of fish farmers and (f) proximity to SD capitals

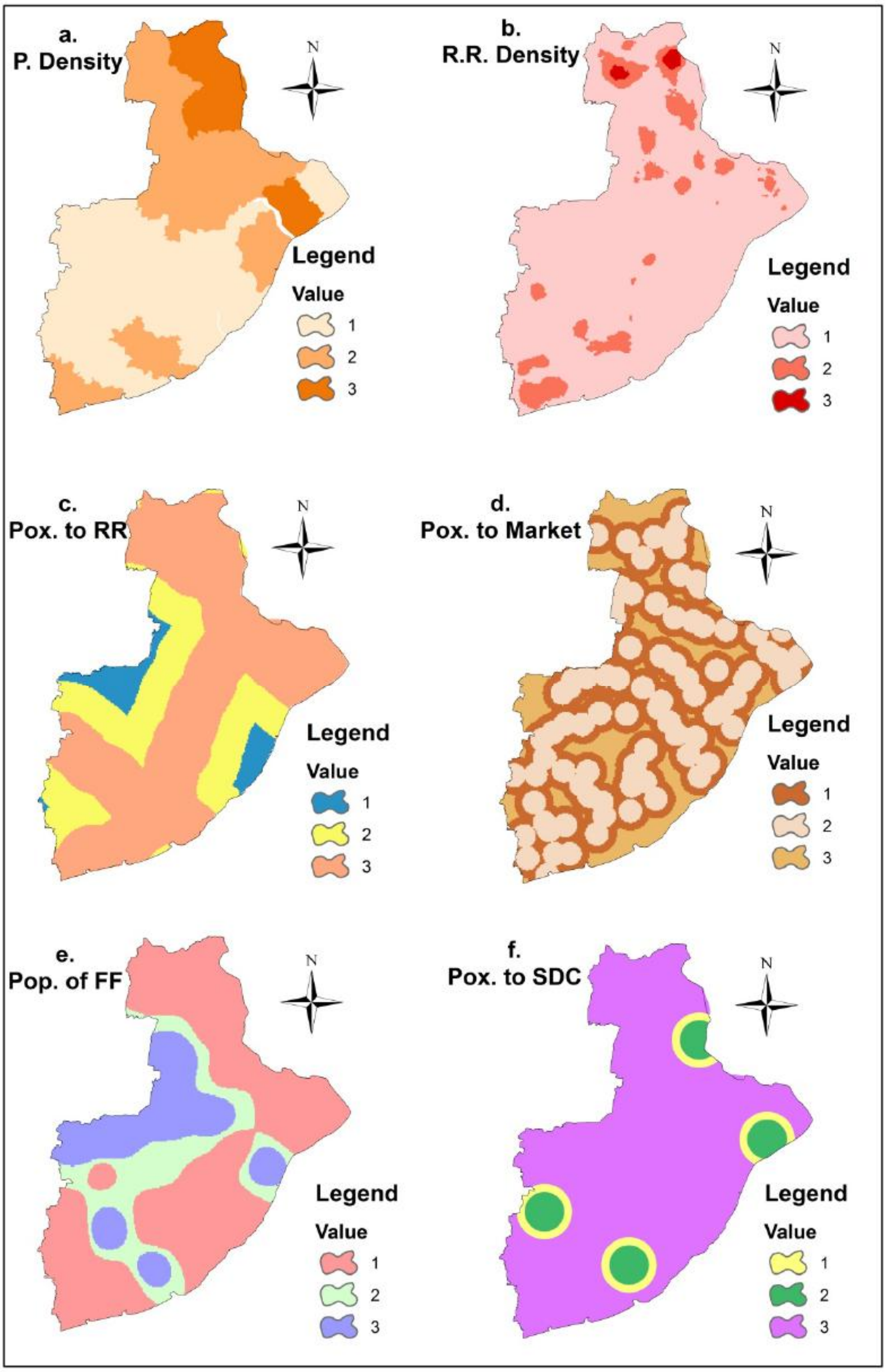

Figure 6.8 Suitability scale for (a) population density, (b) road-rail density, (c) proximity to road, (d) proximity to market, (e) population of fish farmers and (f) proximity to SD capitals

6.3.3 Suitable Site

The result affirms that the existing situation in the study area supports promising opportunity for the establishment and development of aquaculture. The geospatial model based estimated results of SSFF show that area of 77123.40 ha. (19.91 %) is in suitable, 262351.39 ha. (67.71%) is in moderately suitable and 47959.93 ha. (12.38 %) comes under unsuitable category (Table 6.9). The spatial distribution of suitable and potential sites for fish farm is presented in Figure 6.9. Based on the fish living environment, the gradually colour intensity indexed (red to green) map showing the suitability range in the study area (Figure 6.9). Most of the area of Moyna and Bhagawanpur-I blocks are comes into suitable zone, while some parts of Nandigram-III, Bhagawanpur-II, Tamluk (western part), Nandakumar (western part) are also come under suitable zone. On the other hand, Nandigram-I, Haldia, Sutahata, Panskura and some parts of Nandakumar, Nandigram-III and Sahid Matangini etc, blocks are observed in unsuitable zone for fish farming. Potashpur-II, Potashpur-I and Egra blocks etc are sensible in moderate and suitable zone. Mainly the water quality, water availability and soil texture are accountable for this type of distribution pattern.

Accordingly, the overall assessment of SSCFF indicated that 12.16 % (47110.05 ha.) area is found in suitable class for small-scale economic fish farm. The remaining 66.17 % (256374.13 ha.) and 21.67 % (83950.54 ha.) area are categorised as moderately suitable and unsuitable or insignificant for economically favourable fish frrm, respectively (Table 6.9). Model based local distribution of suitable and feasible sites for the commercially benefited fish farm is presented in Figure 6.10. The colour intensity indexed (red to green) map exhibit the distribution of suitable site for commercially viable fish farm (Figure 6.10). Most of the areas of Panskura traverse into suitable class, but few portion of Moyna, Sahid Matangini, Tamluk, Nandakumar-III and Bhagawanpur-I are considered as a suitable areas. On the other hand, blocks of Khejuri-II, Nandakumar-I, Nandakumar-II and Egra-I etc, can be found in inappropriate areas for development of commercially fish farm. Bhagawanpur-I, Ramnagar-I, Nandakumar-II and Potashpur-II etc, blocks are observed as moderately suitable for the development of commercially planned aquaculture farm. The relationship between transportation facility, market demand of rising population density and availability of fish farming environment are responsible for this type of distribution pattern which are influencing for the development of commercial fish farm.

Table 6.9 Detail of suitability pattern of the district

Suitable Scale	SSFF		SSCFF	
	Area (ha.)	Percentage	Area (ha.)	Percentage
3	77123.40	19.91	47110.05	12.16
2	262351.39	67.71	256374.13	66.17
1	47959.93	12.38	83950.54	21.67

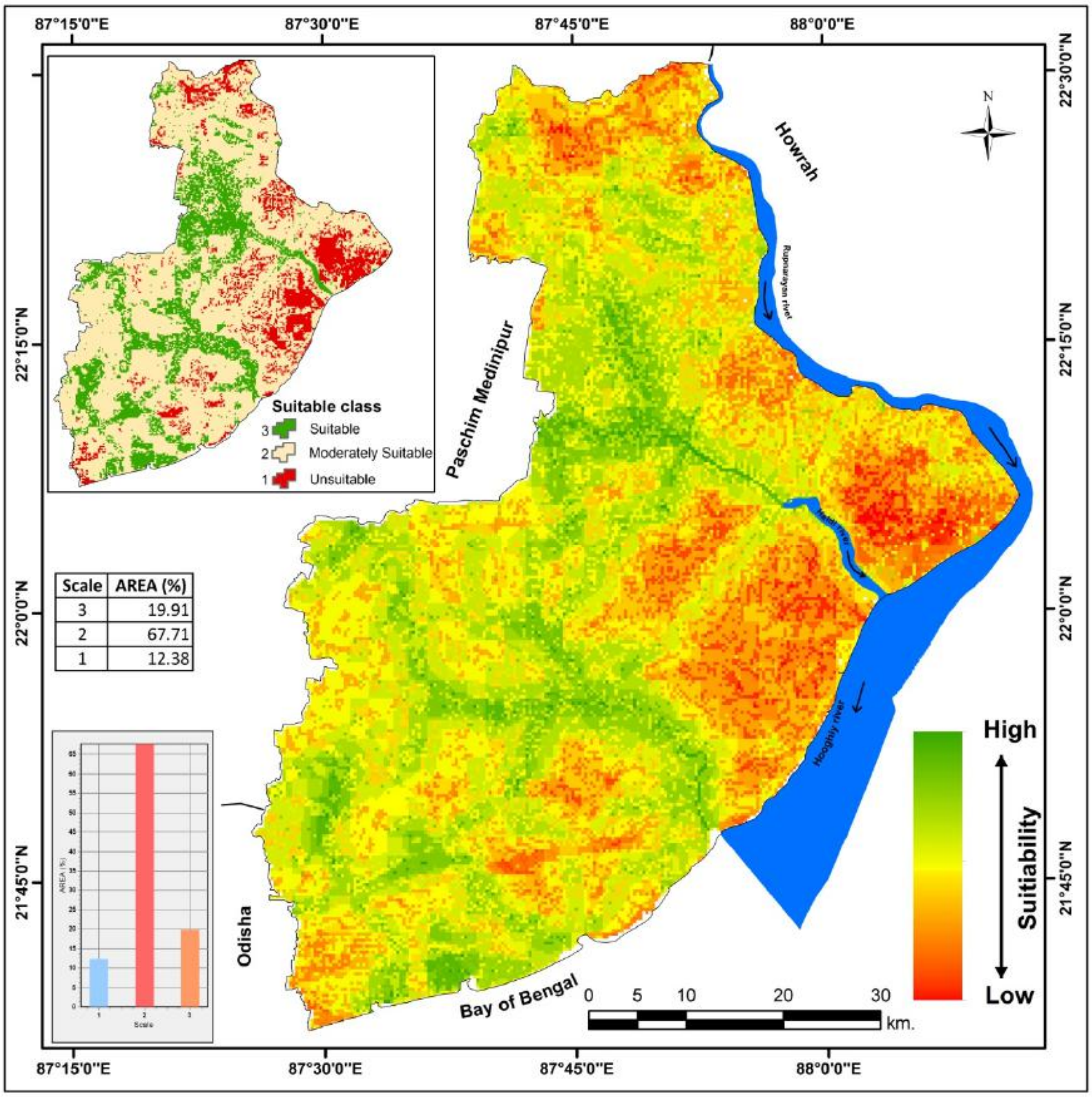

Figure 6.9 Distribution of suitable site based on SSFF model

Sufficient availability of water and environmental qualities for fish growth can be a good influence on small-scale fish farms in this region but commercial fish farming in this area is also limited by fast transportation connectivity, which is the nearby major market and nearest to city. The fish farming instruction and advancements related to scientific fish farming are also found to be an obstacle to hitch up the potential of aquaculture. The supply and production are limited, while the demand for nearest cities, urban and town markets are emerging. Therefore, it is necessary to the development of faster and reliable transportation facilities provide a useful guideline and scientific training for fisherman small-scale aquacultures.

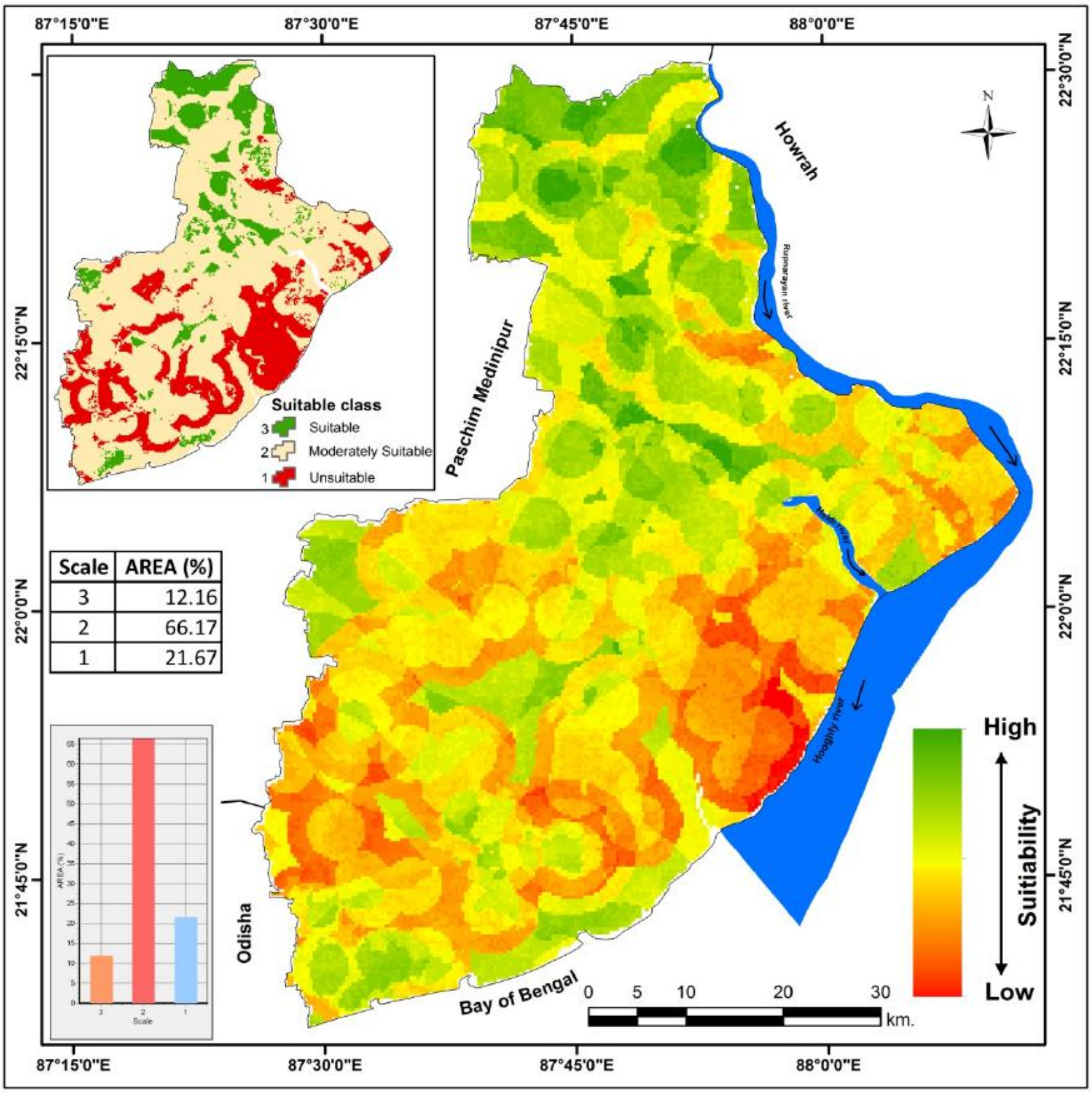

Figure 6.10 Distribution of suitable site based on SSCFF model

6.4 Summary

This chapter summarized the parameters, method, model and distribution of suitable site for aquaculture in Purba Medinipur district. The parameters are also categorized based on suitability scale. The distribution of suitable site has been identified by using multi-criteria geospatial technology. The model based SSFF analysis reveals that the most of the suitable zone has been observed at Moyna and Bhagawanpur-I blocks whereas Nandigram-I, Haldia, Sutahata, Panskura and some parts of Nandakumar, Nandigram-III and Sahid Matangini etc, blocks has been observed as unsuitable zone for fish farm. Site Suitability for Commercial Fish Farming (SSCFF) model shows most of the areas of Panskura, some portions of Moyna, Sahid Matangini, Tamluk, Nandakumar-III and Bhagawanpur-I has been measured as suitable areas for development of economy based fish farm, whereas Khejuri-II, Nandakumar-I, Nandakumar-II and Egra-I etc, has been found unsuitable for development of commercial fish farm.