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Research Article **Open Access**

Land Use and Climate Change Impact on the Streamflow of the Tamirabarani River Basin

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Abstract The study of water resources use to manage, assess and simulate these important natural resources. In Tamirabarani basin the land use pattern around the flood basin area and population density increased. So many area of the river is occupied by the urbanization and deforestation. The climatic conditions also varied. This various problems are affecting the surface water flow. The previous methods of surface water flow involve many manual methods and calculations. The ArcSWAT used to create the streamflow model for the changes in the land use pattern and climatic condition. ArcSWAT can be used to generate valuable information for decision making by producing maps with model output spatially overlaid on other important GIS data. In this ArcSWAT used to develop the model for the water management using the HRU (land use, soil, and slope) units.
Keywords *GIS, Remote Sensing, ArcSWAT, SWAT, HRU*

1. Introduction

Hydrological cycle is the movement, and distribution of the water in earth, ocean and sky. It contains different process such as precipitation, evaporation, transpiration, and etc. Hydrological models are simplified, conceptual representations of a part of the hydrologic cycle (1). But creating the models manually then it's contain many equations, calculations and time consuming process. ArcSWAT is the extension tool of ArcMap9.3. It is used to create the streamflow model in easily; timing of the process is low and the accuracy is high (2).

1.1. Study Area

The Tamirabarani basin is situated between 08º8'N and 09º23'N latitude and 77º09'E and 77º54'E longitude with area of the basin is 5942 km^2, total catchments area of 4500 km^2 with population density = 362 person per km^2. Annual rainfall prevails over up to 814.8 mm per annum. Total length of river is 120 km of which 75 km in Tirunelveli district. The Papanasam reservoir is 16 km downstream. It is fed both by monsoon and by its tributaries. The location of the study area shown in figure 1.1.

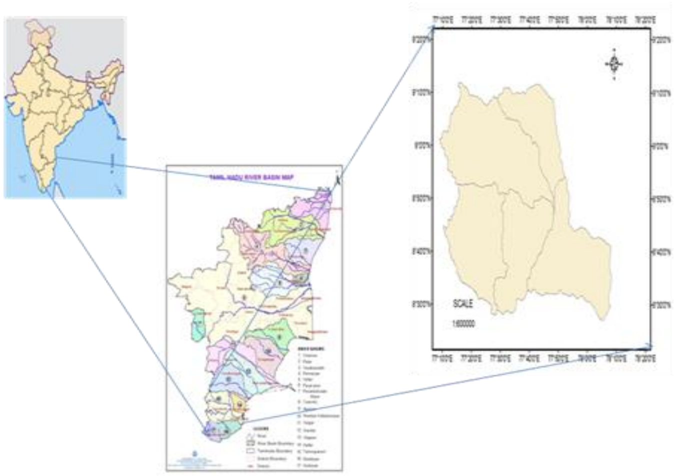

Figure 1.1: *Location Map of the Study Area*

2. Materials and Methods

The following factors are used to create surface water model: DEM, Slope, Soil type, Land use/Land cover data, Rainfall, Stream flow and Min & Max Temperature (3). The climate data, soil and LU/LC data's are collected from the PWD (Public Work Department) and IWS (Institute of Water Studies).

2.1. Digital Elevation Model

DEM is the elevation of any point in a given area at a specific spatial resolution (4). This DEM data of my study area download from the SRTM (Shuttle Radar Topography Mission). The DEM was used to delineate the watershed and to analyze the drainage patterns of the land surface terrain. Subbasin parameters such as slope gradient, slope length of the terrain, and the stream network characteristics such as channel slope, length, and width were derived from the DEM. At first DEM data is taken that change the coordinate system and insert the DEM data in ArcSWAT (5).

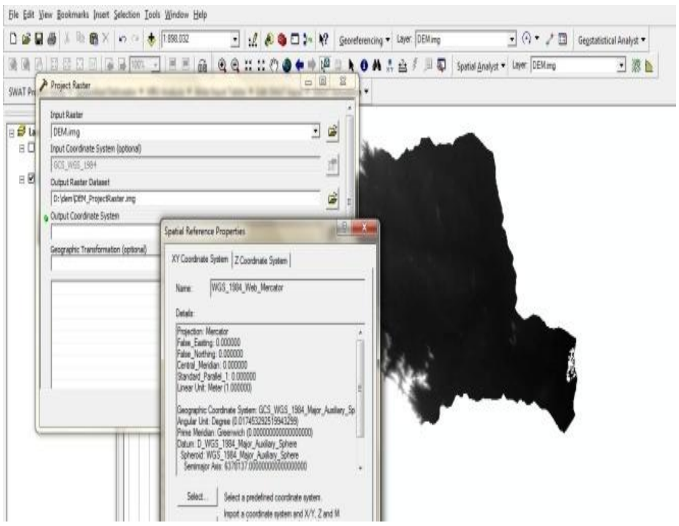

Figure 2.1: *Project the DEM Data*

The raster DEM data is project with the WGS1984 web Mercator projection system (5).

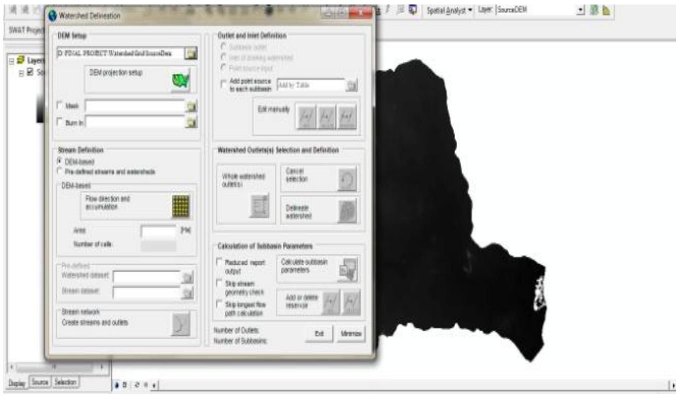

Figure 2.2: *Insert the DEM Data in ArcSWAT*

The slope data of our study area derived from the DEM data (4).

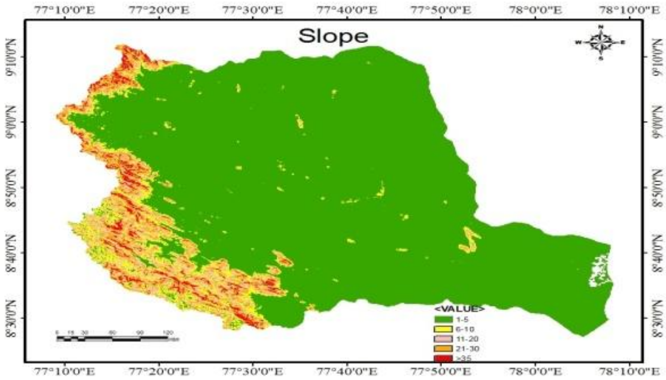

Figure 2.3: *Slope Map of the Study Area*

After inserting the DEM data the flow directions are calculated. The basin inlet and outlet is given manually then the watershed delineation is done (4). The subbasin parameters are calculated. This report saved as a text (.txt) file format.

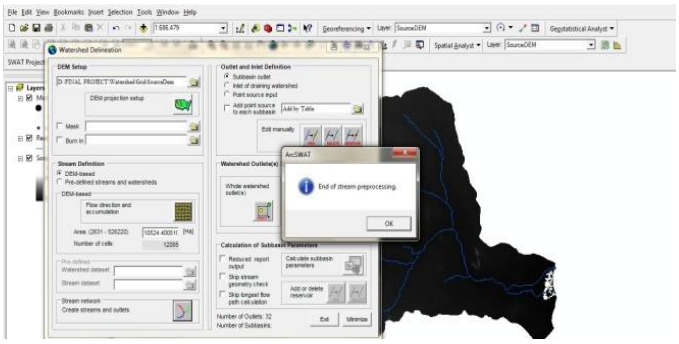

Figure 2.4: *Calculate the Stream Flow from the DEM Data*

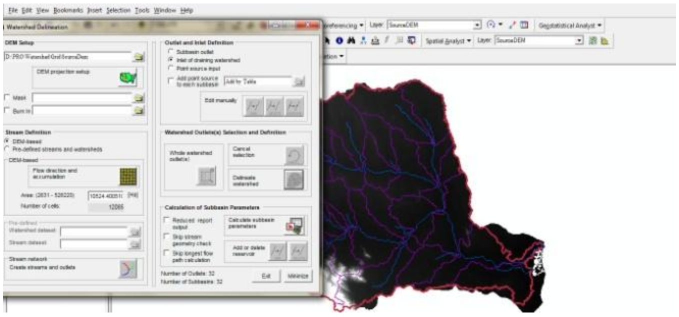

Figure 2.5: *Watershed Delineation from the DEM Data*

2.2. Soil Data

The soil map of the study area collected from the IWS (Institute of Water Studies) Chennai. SWAT model requires different soil properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type (6).

The soil type data (.shp) edit in the ArcSWAT and change the format to (.sol) & (.chm) data. In this soil type given as table format, it does also have 5 types in enter the Soil data: Name, Stmuid, Stmuid+name, Stumid+sequence and S5id (2).

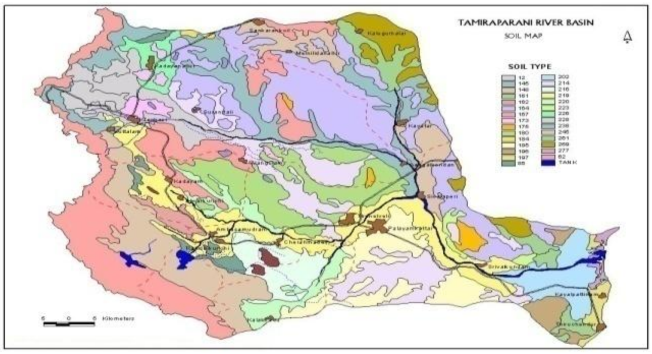

Figure 2.6: *Soil Data of the Study Area*

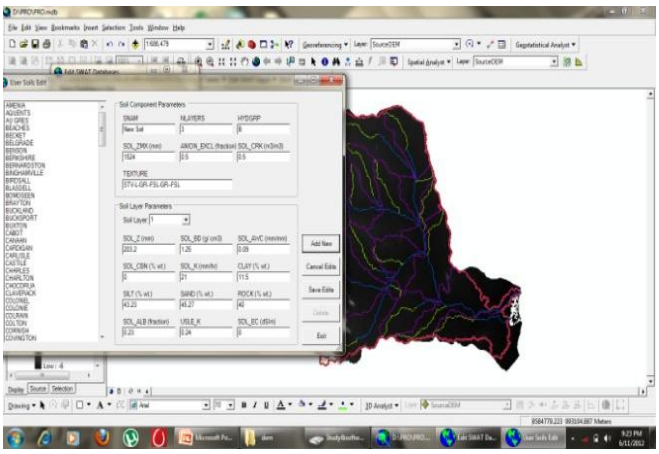

Figure 2.7: *Edit the Soil Data in ArcSWAT*

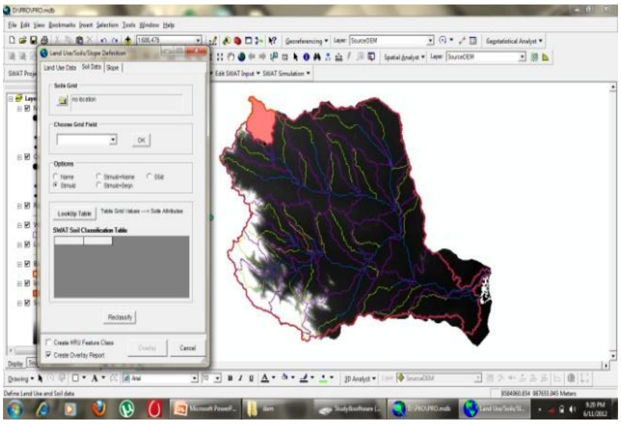

Figure 2.8: *Enter the Soil Data in ArcSWAT*

2.3. Land Use Data

Land use is one of the most important factors that affect runoff, evapotranspiration and surface erosion in a watershed (4). The land use map of the study area was obtained from the IWS Chennai. The satellite imagery of IRS-P6 23.5 m resolution is taken. The land use data 2006-2010 data taken for the land use changes.

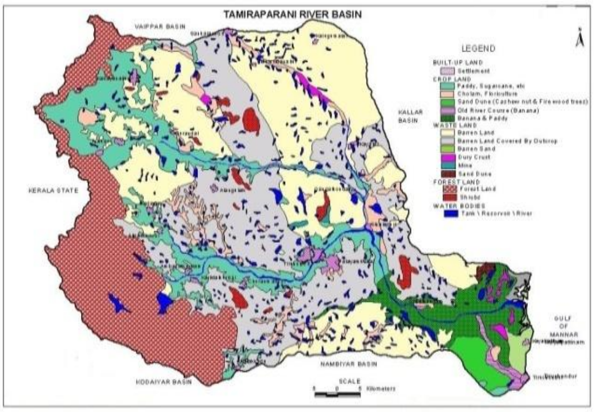

Figure 2.9: *Land Use Map of 2006 of Study Area*

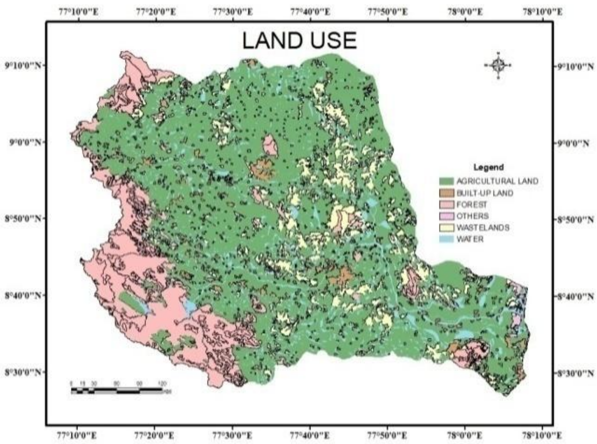

Figure 2.10: *Land Use Map of 2006 of Study Area*

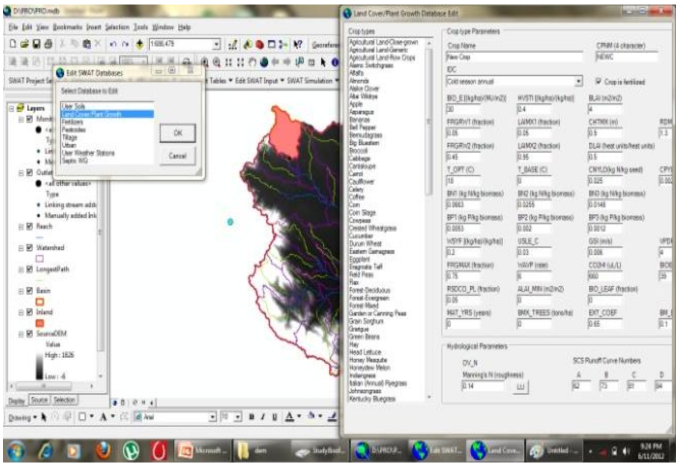

Figure 2.11: *Edit the Land Use Data in ArcSWAT*

In this ArcSWAT edit the land use and urban data and changes the format from the shape file and enter the data in ArcSWAT (4).

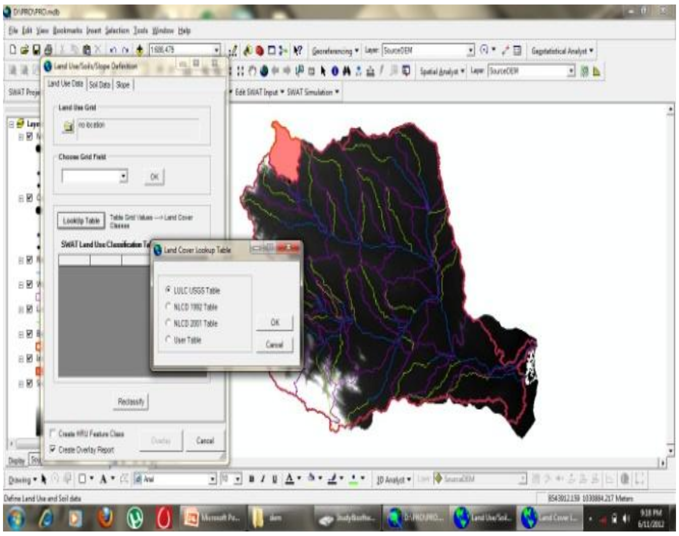

Figure 2.12: *Enter the Land Use Data in ArcSWAT*

2.4. Slope Reclassification

In this slope tap the number of classes in slope (maximum 5). Give the range in percentage via for each slope class then slope of the study area is generated (3).

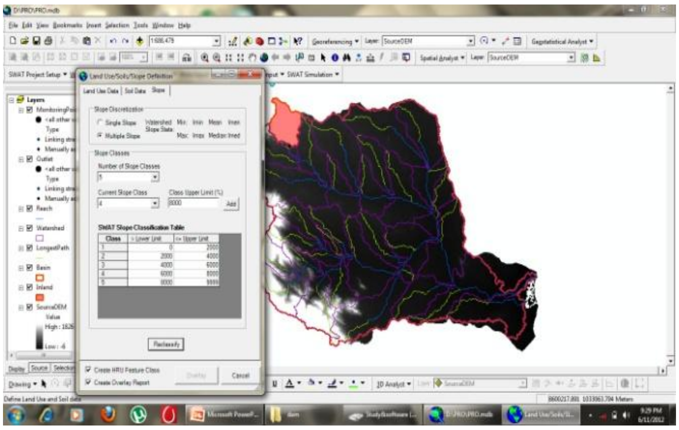

Figure 2.13: *Slope Data of the Study Area*

2.5. HRU Overlay & Analysis

The Slope, Soil and Land use of the study area is called as Hydro Response Units. After enter the HRU unit then the rank of that area is preferred depends upon the overlay (3).

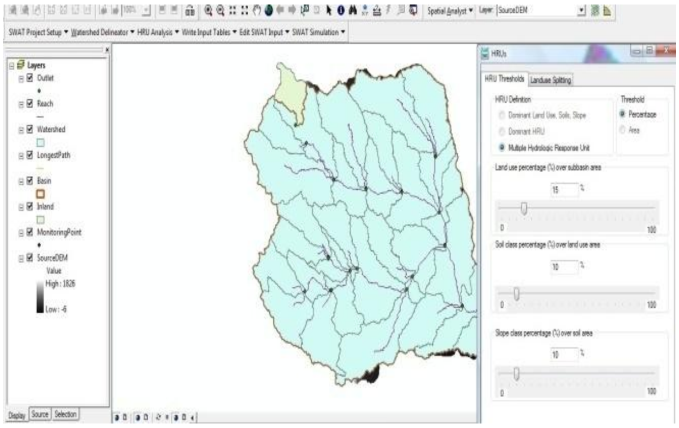

Figure 2.14: *HRU Analysis of the Study Area*

2.6. Weather Data

These data's (precipitation, evapotranspiration, min & max temperature, wind speed and relative humidity) were obtained from IWS (Institute of Water Studies) Chennai. In this weather data is given as the excel format change the data format using ASCII code format to (.WGN) file (3). In this weather input data tab give the date of weather data (1/1/2006) to (31/12/2010) and enter the data's in ArcSWAT.

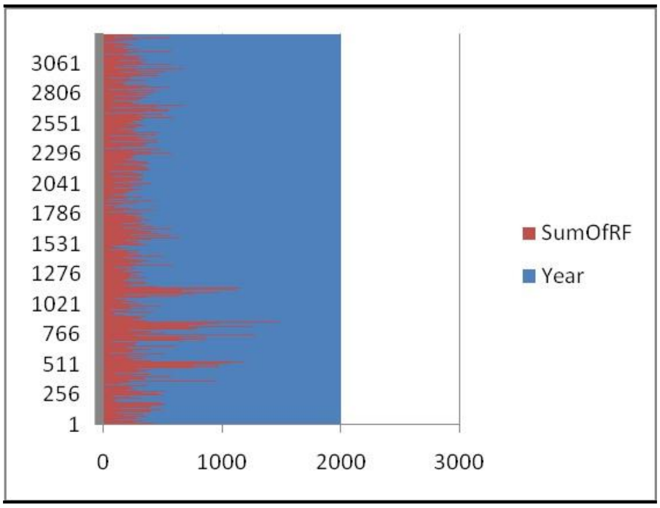

Figure 2.15: *Changes in the Rainfall*

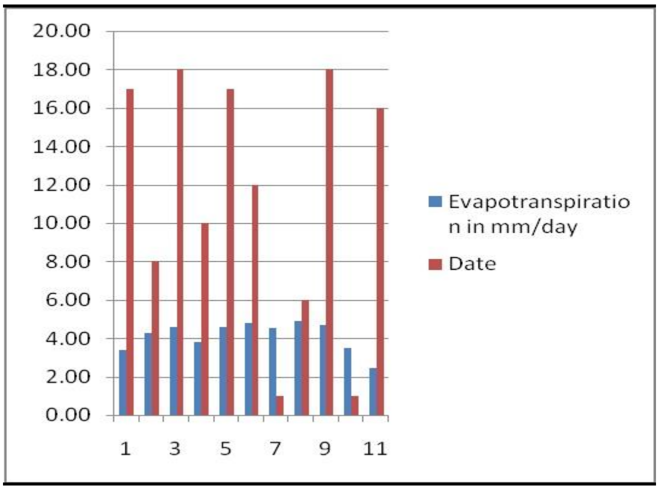

Figure 2.16: *Changes in the Evapotranspiration*

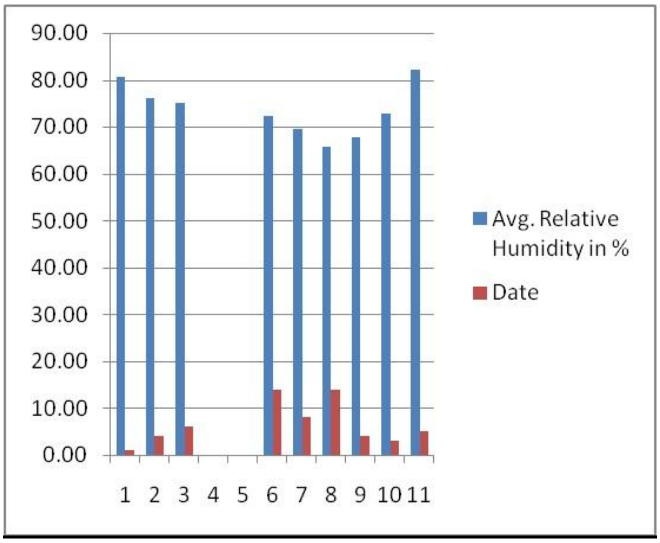

Figure 2.17: *Changes in the Relative Humidity*

This data's available in the excel sheet. Put this data into ArcSWAT and change the format to (.wgn) file and enter the data in ArcSWAT (3).

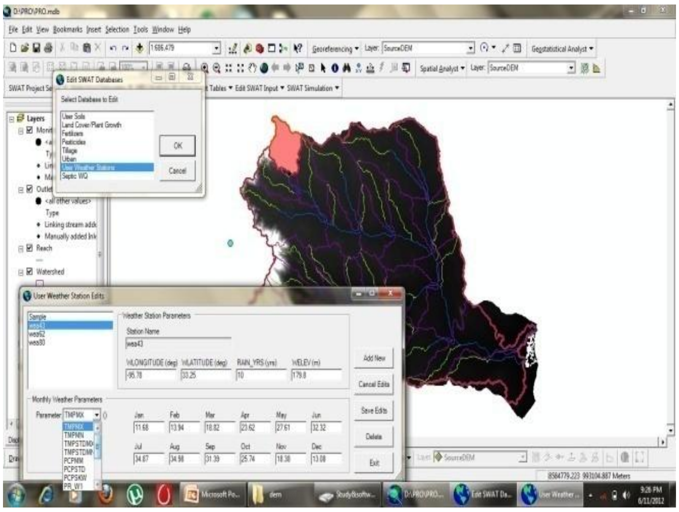

Figure 2.18: *Enter Weather Data in ArcSWAT*

3. Setup & Run the Simulation

After giving the inputs in ArcSWAT and now go to the setup tap and run. In this tab we give date for the simulation period (1/1/2006 to 31/12/2010) and click the Run button then simulation will start (2).

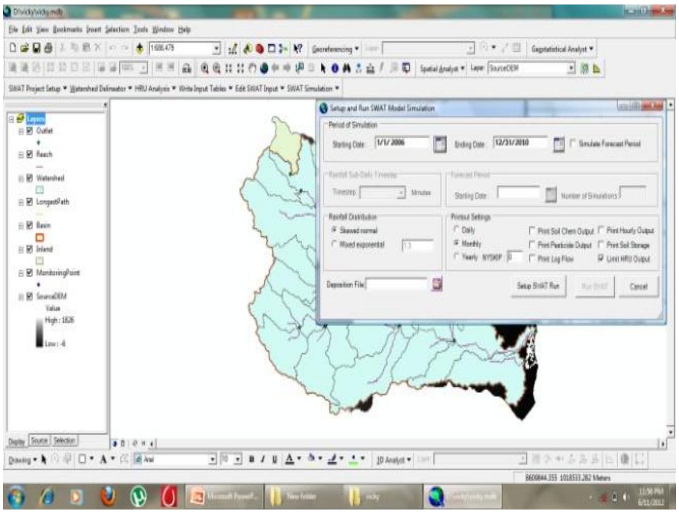

Figure 3.1: *Setup and Run the ArcSWAT*

3.1. Simulation Report

After complete the simulation the simulation report was generated as .rch file. From this file we able to calculate the stream flow in month wise for the total years. Now we compare the streamflow for the observed flow and simulated flow (2).

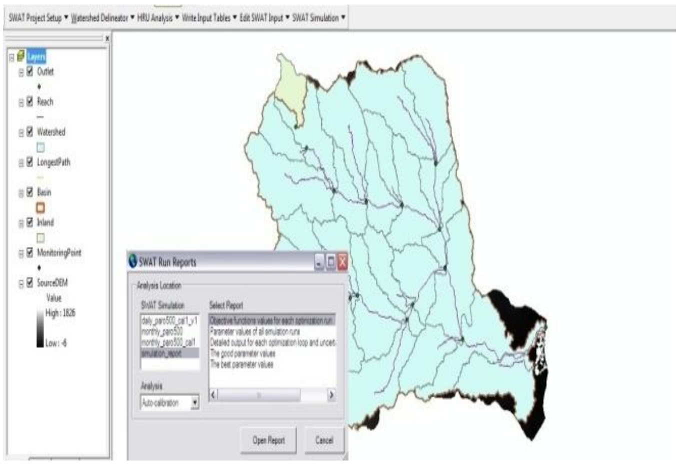

Figure 3.2: ArcSWAT Simulation Report

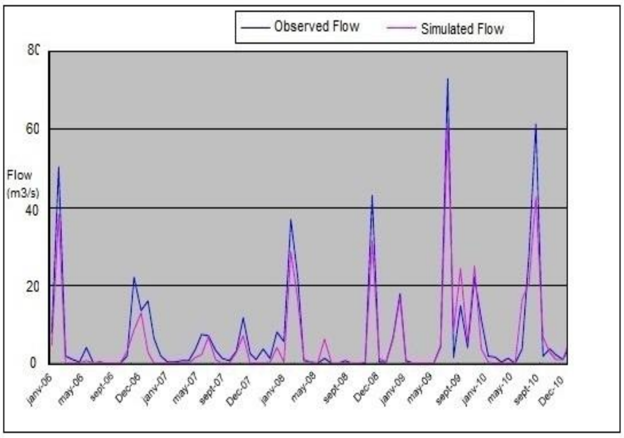

***Figure 3.3:** Comparison of Monthly Observed and Simulated Flow Stream for the Period (2006-10).*

4. Conclusion

The SWAT model was successfully calibrated in the Tamirabarani river basin. The model produced good simulation results for monthly average stream flow as for the other water balance components. The evaluation of the model performance was carried out successfully with the recommended statistical coefficients. These performances can be enhanced furthermore using more accurate input data especially for the soil and temperature features that were estimated in this study with global data. The output of this study may support planners and decision makers to take relevant soil and water conservation measures and thereby reduce the alarming soil loss and land and degradation problems in the basin.

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Evaluation of Fluoride Contamination in Groundwater Using Remote Sensing and GIS Techniques in Virudhunagar District, India

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Abstract The prevalence of fluoride is mainly due to the consumption of more fluoride through drinking water. It is necessary to find out the fluoride contamination areas to adopt remedial measures to the people on the risk of fluorosis. The groundwater fluoride causes by rock water interaction. The occurrence of dental fluorosis among the people in the Virudhunagar district provides the motivation to investigate occurrence of fluoride in groundwater. The objective of the study is to find out the spatial distribution of fluoride in pre-monsoon and post-monsoon period using GIS and remote sensing. The fluoride concentration in groundwater varies from 0.2 mg/l to 1.6mg/l in pre-monsoon and 0.1mg/l to 1.9mg/l in post-monsoon. The overall distribution of fluoride concentration in the study area during the pre-monsoon and post-monsoon periods indicates slight dilution effect owing to fresh water recharge on account of rain fall. Exposure of fluoride among different age group was calculated in this study area. From the results, the fluoride concentration was identified to be 33% in pre-monsoon period and 25% in post-monsoon period in Virudunagar district, Kavalur, Rajapalayam, Srivilliputtur, Vembakottai, and Watrap blocks were highly affected, but the neighboring blocks are free from excess fluoride contamination in drinking water. It has been recommended to the government authorities to take serious steps to supply drinking water with low fluoride concern for the fluorosis affected areas.

Keywords GIS, Remote Sensing, Fluoride

1. Introduction

Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps preventing and even reverse the early stages of tooth decay. The weathering of primary rocks and leaching of fluoride-containing minerals in soils yield fluoride rich groundwater in India which is generally associated with low calcium content and high bicarbonate ions (1). The unfettered groundwater tapping exacerbates the failure of drinking water sources and accelerates the entry of fluoride into groundwater. Dental fluorosis, which is characterized by discolored, blackened, mottled or chalky-white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing. These effects are not apparent if the teeth were already fully grown prior to the fluoride overexposure; therefore, the fact that an adult may show no signs of dental fluorosis does not necessarily mean that his or her fluoride intake is within the safety limit. Chronic intake of excessive fluoride can lead to the severe and permanent bone and joint deformations of skeletal fluorosis. The only remedy is prevention by keeping fluoride intake within safe limits.

1.1. Description of the Study Area

The study area Virudhunagar is located in southern part of Tamil Nadu state. It is spread across of 4243 sq.kms. It lies between $9^0$15'0"N to $9^0$44'0"N latitudes and $77^0$27'00"E to $78^0$17'0"E longitudes, in the state of Tamil Nadu (Figure 1.1). It is bounded by Madurai district on the north, Sivagangai district on the northeast, Ramanathapuram district on the southeast, Thoothukudi district to the south, Tirunelveli district to the southwest, Kerala state to the west, and Theni district to the northwest. The normal annual rainfall over the district varies from about 757 mm to 987 mm.

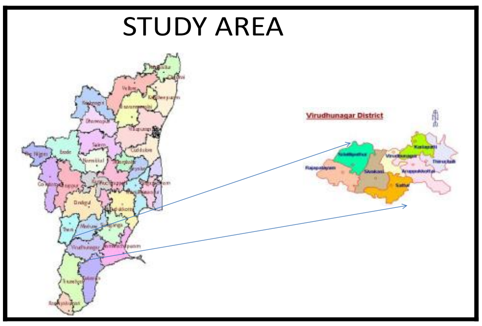

Figure 1.1: Study Area Location

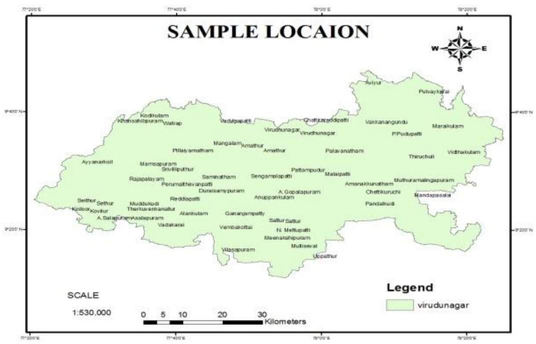

Figure 1.1a: Sample Location

2. Materials and Methods

The fluoride map was created for Virudhunagar district by using GIS software. Bore well and dug well water quality data are used to evaluate the fluoride level in pre-monsoon and post-monsoon period. Data acquisition involves with the collection of toposheet, water quality data, rainfall data and population census data for the study area. The spatial data of study area such as base map, land use, fluoride, and population were derived in the form of maps in the same scale using ArcGIS 9.3 land use map, fluoride map and population map. A total of 63 groundwater samples were collected from CGWB bore wells, dug wells etc (2). The geographical information of dug well and bore well has been changed degree minute to decimal degree. The amount of fluoride in drinking water in Virudunagar district was used as resource data to create the fluoride database by using Microsoft excel and access programs.

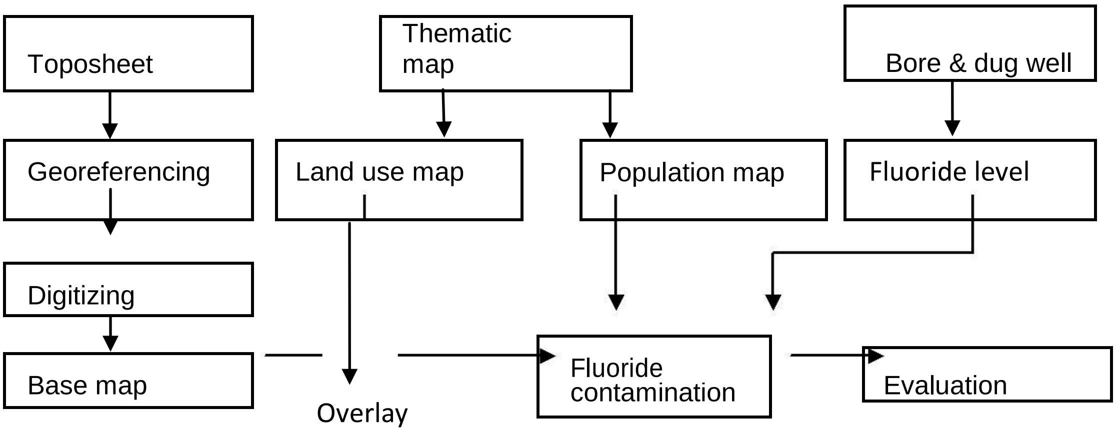

Figure 2.1: Methodology of the Study

The fluoride database was redesigned as relational database so that it can be linked to another database such as spatial data. GIS is a tool to define risk areas that require planning for fluorosis prevention program because of GIS's features and capability in model and data processing with attribute and spatial data (3). ARCGIS provides a broad range of powerful spatial modeling and analysis feature. GIS analysis perform integrate raster data and vector data analysis (4).Using the tools of spatial analysis, geo statistical analyses, & 3d analyst. Fluoride database is used and classified into 4 classes, it is linked together with spatial data to create map layout in GIS (5). According to WHO, 1971, permissible limit for fluoride in drinking water is 1.0 mg/l, whereas USPHS, 1962 has set a range of allowable concentrations for fluoride in drinking water for a region depending on its climatic conditions because the amount of water consumed and consequently the amount of fluoride ingested being influenced primarily by the air temperature.

Annual Average of Maximum Daily Air Temperature (◦C)	**Recommended Fluoride Concentration (mg/l)**			**Maximum Allowable Fluoride Concentration (mg/l)**
	Lower	**Optimum**	**Upper**	
10 – 12	0.9	1.2	1.7	2.4
12.1 – 14.6	0.8	1.1	1.5	2.2
14.7 – 17.7	0.8	1.0	1.3	2.0
17.8 – 21.4	0.7	0.9	1.2	1.8
21.5 – 26.2	0.7	0.8	1.0	1.6
6.3 – 32.5	0.6	0.7	0.8	1.4

Table 2.1: Fluoride Concentration Specified by WHO

Villages	TDS	NO3	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3	F	pH	EC	TH
N. Mettupatti	1982	68	184	199	196	17	748	221	0	226	0.2	8.0	3390	1280
A.Gopalapuram	642	29	110	27	78	2	106	24	0	329	0.5	8.0	1080	385
A.Salapuram	711	1	92	61	94	7	199	24	0	458	0.7	8.0	1340	480

All values are in mg/l, except pH and EC. Units of EC are mmho/cm

Table 2.2: Concentration of Chemical and Physical Parameters in Ground Water Pre-Monsoon Period

Villages	TDS	NO3	CA	MG	NA	K	CL	SO4	CO3	HCO3	F	PH	EC	TH
N. Mettupatti	1057	22	120	49	189	10	298	106	0	372	0.6	7.8	1800	500
A.Gopalapuram	487	17	98	10	64	1	60	27	6	244	0.6	8.4	810	285
A.Salapuram	659	1	66	51	115	5	195	27	0	390	0.7	7.7	1230	375

All values are in mg/l, except pH and EC. Units of EC are mmho/cm

Table 2.3: Concentration of Chemical and Physical Parameters in Ground Water Post-Monsoon Period

2.1. Study Area Population

Total population is 1,943,309 male and female were 967,437 and 975,872 respectively. Total area of Virudhunagar district was 4,283 with average density of 454 per sq.km. Virudhunagar population constituted 2.69 percent of total Tamil Nadu population. Average literacy rate of Virudhunagar in 2011 were 80.75. If things are looked out at gender wise, male and female literacy were 88.46 and 73.14 respectively. The sex ratio in Virudhunagar is at 1009 per 1000 male.

3. Results and Discussion

3.1. Fluoride Exposure Dose

The fluoride exposure doses were calculated by the following generic equation:

Exposure Dose = (C * WI) / BW Where, C — fluoride concentration (mg/l), WI — water intake (l/d), and BW — body weight (kg). For the calculation, it was assumed chronic exposure and total bioavailability of fluoride in water. The water intake of different age group was estimated to infants in their budding life drank 250 ml of boiled water per day, used in the reconstitution of milk formulas. In boiled water, fluoride level increases proportionally to the loss of volume, so the concentration of fluoride in tap water was doubled (6). The estimated water intake for children and adult was 1.5 and 3.0 l per day respectively. For the calculation, body weight of infants in the age group of 0 to 6 months was kept as 6 kg. Children between 7 year to adulthood as 20 kg body weight and that of adults above 19 years as 70 kg. The mean of minimum and maximum range of water fluoride level in each well was used for minimum and maximum exposure dose calculation.

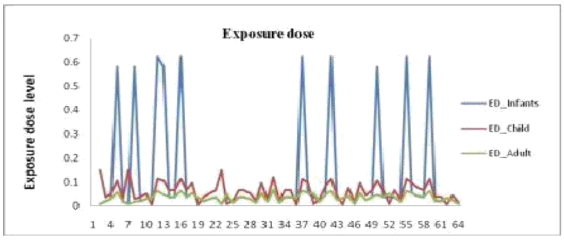

Figure 3.1: Pre-monsoon Exposure Dose

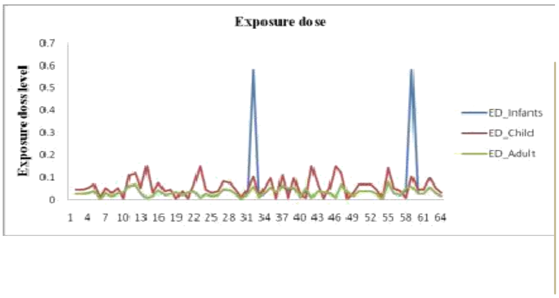

Figure 3.2: Post-monsoon Exposure Dose

3.2. Correlation

The correlation is one of the most common and most useful statistics. A correlation is a single number that describes the degree of relationship between two variables. Let's work through an example to show you how this statistic is computed.

Correlation Matrix: This is about to compute a correlation between two variables. In most studies we have considerably more than two variables. Let's say we have a study with 10 interval-level variables and we want to estimate the relationships among all of them (i.e., between all possible pairs of variables (7). A simple statistics program to generate random data for 10 variables with 20 cases for each variable. Then, to compute the correlations among these variables.

	TDS	*NO3*	*Ca*	*Mg*	*Na*	*K*	*Cl*	*SO4*	*CO3*	*HCO3*	*F*	*pH*	*EC*	*TH*
TDS	1													
NO3	0.7153	1												
Ca	0.838993	0.671852	1											
Mg	0.474055	0.65076	0.354648	1										
Na	0.959903	0.563747	0.707269	0.28872	1									
K	0.110596	0.311049	0.201041	0.101992	0.00855	1								
Cl	0.986678	0.690952	0.864342	0.491081	0.932928	0.08761	1							
SO4	0.954246	0.650816	0.76743	0.441786	0.924165	0.114121	0.910534	1						
CO3	0.71397	0.250354	0.599766	0.044265	0.771288	-0.07686	0.726026	0.654131	1					
HCO3	0.601155	0.311666	0.275447	0.178401	0.692272	-0.03409	0.514491	0.572054	0.397598	1				
F	0.170676	-0.05752	-0.03986	-0.03733	0.264137	-0.22779	0.107491	0.241433	0.060116	0.470379	1			
Ph	0.615423	0.20275	0.539317	0.189849	0.62881	-0.06082	0.648951	0.544188	0.784528	0.308242	0.035319	1		
EC	0.999059	0.717178	0.840206	0.501595	0.952863	0.101779	0.988346	0.950405	0.703158	0.600867	0.169137	0.615023	1	
TH	0.829178	0.80055	0.8825	0.752714	0.643197	0.192712	0.855581	0.762525	0.444334	0.283753	-0.04663	0.474915	0.843882	1

Table 3.1: Correlation Matrix for the Study Area Pre-monsoon

3.3. Fluoride Level

The concentration of fluoride above 1 mgl was observed in 13 wells and remaining wells in safe limit. The higher concentration is due to the over exploitation of the groundwater and the geological formation. The concentration of fluoride is mainly due to the rock water interaction. Recharging the groundwater in the higher concentration area may improve the groundwater quality.

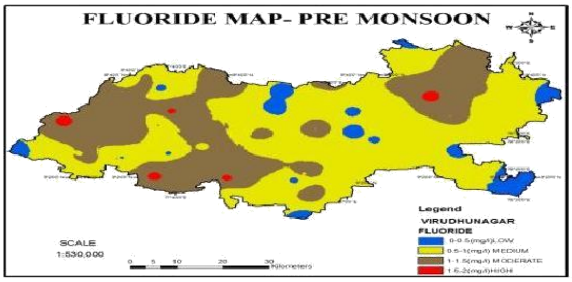

Figure 3.3: Pre-monsoon Fluoride Map

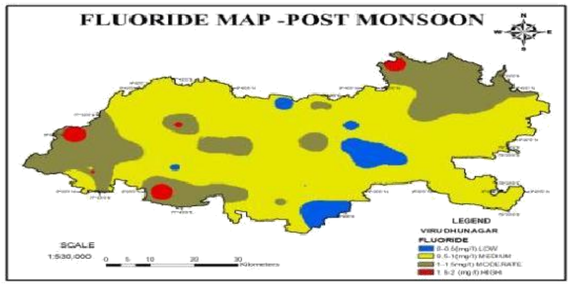

Figure 3.4: Post-monsoon Fluoride Map

3.4. Land Use

Major land use in the study area is covered by agriculture and forest. The different land use patterns identified were agriculture, forest, built-up area, water bodies and waste land. Samples were collected from the entire land use pattern in the pre-monsoon and the post-monsoon period (8). The table shows the samples of the land use the pattern.

3.5. Overlay

Overlays are another common cartographic modeling operation. An overlay is the primary way to combine information from two separate themes. Overlays are most common for polygonal data, and perform a geometric intersection, which results in a new layer with the combined attributes of both initial layers. The ArcGIS overlay analysis performed intersect between land use map and fluoride levels. These Alangulam, Chattirareddipatti, Khansahibpuram, Mamsapuram, Sattur, Srivilliputhur, and Subramaniyapuram have 0.5 range of low fluoride level in post-monsoon compare to pre-monsoon period.

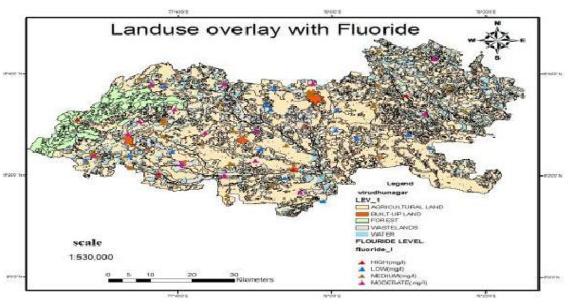

Figure 3.5 Land use pre-monsoon

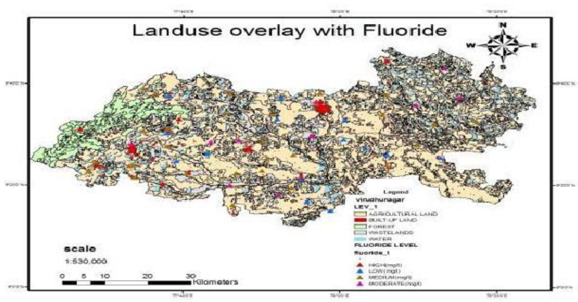

Figure 3.6 Land use post-monsoon

Period	Agriculture	Water Bodies	Forest	Waste Land	Built-up Land
Population percentage	52.2	0	0.44	0.16	46.6
Pre- monsoon samples	31	0	1	5	22
Pre-monsoon fluoride average	0.8	0	1.5	1.28	0.75
Post-monsoon samples	31	0	1	5	22
Post -monsoon fluoride average	0.8	0	1.6	0.8	0.609

Table 3.2: Land Use with Pre-monsoon and Post-monsoon Fluoride Level

4. Conclusion

The present geohydrological investigation was carried out with appropriate and state-of-the-art methodologies to meet the declared objectives. The work also integrates rainfall, land use, identifying the fluoride contamination region in the study area.

From the data interpretation very low rainfall in the winter season and high rainfall in the Northeast monsoon is observed. The study area samples chemical analysis shown fluoride is highly negative correlated with potassium and highly positive correlated with hydrogen carbonate. The correlation matrix shown the pre-monsoon period fluoride is correlated with potassium -0.222 and hydrogen carbonate correlate 0.47003 then post monsoon periods fluoride is correlated with potassium is -0.35206 and hydrogen carbonate is 0.238883.

The study was carryout in accordance with the declared methodology. The analysis was made in GIS for identifying the evaluation fluoride contamination region in the study area. The concentration of fluoride above 1 mg/l was observed in 21 samples in pre-monsoon 16 samples in post-monsoon and remaining samples in safe limit. The higher concentration is due to the over exploitation of the groundwater and the geological formation. The concentration of fluoride is mainly due to the rock water interaction. Recharging the groundwater in the higher concentration area may improve the groundwater quality. This study identified that 33% in pre-monsoon and 25% in post-monsoon in Virudhunagar district. Kavalur, Rajapalayam, Srivilliputtur, Vembakottai, Watrap blocks were highly affected, but the neighboring blocks are free from excess fluoride contamination in drinking water. People of all age groups are faced with higher risk of fluorosis in Virudhunagar district and infant’s child and adults were highly affected in pre-monsoon period. In pre-monsoon period built-up areas are highly affected compare to post-monsoon period. Mapping of high fluoride areas are useful to plan and to bring safe drinking water from low fluoride areas.

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Research Article **Open Access**

Marine Fishery Information System and Aquaculture Site Selection Using Remote Sensing and GIS

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Abstract In this paper, the Marine Fishery Information System (MFIS) has been suggested with the help of Remote Sensing (RS) and Geographic Information System (GIS). The information system provides the suitable site for aquaculture including offshore and onshore of the Tuticorin coastal area of Tamilnadu and Marine Fish Resources System (MFRS) provides location details about the fish resources such as prawn grounds, pearl oyster beds, small fishes and chunk beds in Gulf of Mannar, India. The site suitability analysis for aquaculture delineate with the help of Multi Criteria Evaluation (MCE) technique. RS and GIS have a decisive role in providing regular, synoptic, multi-spectral coverage of an area. With the launching of the Indian Remote Sensing Satellites (IRS) a wide range of RS data at different spatial and spectral resolutions are now available for the monitoring and management of natural resources. GIS technique help in the integration of databases covering a variety of relevant parameters in an efficient manner. The several parameters are considered in site selection such as conflicting uses of area, settlements, waste lands, salt pan, pollution, depth profile, distance from the sea, distance from the land, coastal topography, and water bodies, soil, geology and geomorphology. The main goal of this research is to delineate the suitable area for aquaculture and marine fish resources mapping through the various image processing technique, field survey and GIS analysis, using remotely sensed data, bathymetry sounding point, electronic navigational chart and various parameters data bases.

Keywords *Remote Sensing, Geographic Information System, Multi Criteria Evaluation, Image Processing, Field Survey, LANDSAT, IRS, Tuticorin, Aquaculture, Marine resources.*

1. Introduction

GIS, Remote Sensing and Mapping have a task to play in all geographic and spatial aspects of the development and management of marine [1]. Aquaculture and Marine Fishery Information System (MFIS), satellite, airborne, ground and undersea sensors acquire much of the related data, especially data on temperature, current velocity, wave height, chlorophyll, and sedimentation concentration, settlements and land and water use [2,3]. GIS is used to manipulate and analyze spatial and attribute data from all sources. It is also used to produce reports in map, database, and statistics, field calculation, and analysis and text format to facilitate decision-making [4]. Land and water is the basic unit of all material production. It is a scarce and in expansible resource which has to be used very judiciously to meet the expectation of the people and competing demands of the nation. The land and water resources base of a country would be able to support the needs of the growing population, provided the resources are used in a rational and judicious manner [5]. But this not happening in many states, including Tamil Nadu which is a cause to all of us engaged in the management of land resources in the country at present [6].

Improper management of natural resources, planning, and devastation of the earth resources leads to economic problem and poverty [7]. Aquaculture and Mari-culture plays vital role in economy of India. Production of these marine foods helps to improve economy growth of country and it gives greater extend to provide employment opportunities for the rural people [8]. GIS and RS is an efficient tool to plan for Aquaculture and Mari culture management with flexible arrangement of resource allocation [1]. The various physical, biological and chemical parameters can analyse in GIS environment and helps to find the area which is suitable for aquaculture including onshore and offshore [2]. The Remote Sensing data gives appropriate information about area with their natural characteristics, these properties helps to analyse various features in ground and aid to manage the resources available in the earth [9].

2. Study Area and Description

The study area is Tuticorin coastal area falls in the latitudinal and longitudinal extensions of 8°40’ to 8°55’ North and 78°0’ to 78°15’ East on the Tamil Nadu, East Coast of India. An onshore aquaculture site selection covers 26 coastal villages of Tuticorin coast such Vembar, Periasamipuram, Mariyakudichattiram, VaipparI, Kallorani, Pattinamaradur, Taruvaikullam, Keelarasadi, Mapillaivurai, Pulipanjankulam, Sanakaraperri, Tuticorin, Mellavittan, Mullakadu Reserved Forest I, Mullakadu Reserved Forest II, Mullakadu, Palaikayal, Mukkani, Punnakayal, Kayalpattinam South, Udankudi, Virapandiyapattinam, KilTiruchendur, Kulasekerapattinam, Manapadu and Madavankurichi. The off shore aquaculture includes 163.5 km of coastal area. Marine fishing, pearl and valamburi chunk fishing are famous in this district from the time immemorial. Thoothukudi is the main centre for deep sea fishing in the district which has a lengthy coast-line of about 140 km. The study area for MFRS is Gulf of Mannar covers approximately an area of 10,500 sq.km along 8°35' N - 9°25' N latitude and 78°08' E - 79°30' E longitude. The Gulf of Mannar is a large shallow bay forming part of the Laccadive Sea in the Indian Ocean. It lies between the south eastern tip of India and the west coast of Sri Lanka. A chain of low islands and reefs known as Adam's Bridge, also called Ramsethu, which includes Mannar Island, separates the Gulf of Mannar from Palk Bay, which lies to the north between India and Sri Lanka.

3. Methodology

The main methodology of this project is to prepare thematic maps with the application of RS and GIS software. All the thematic maps will prepare at the scale of 1:24000. Various GIS analysis and image processing technique will be followed to identify the suitable site for aquaculture and marine resources mapping with the help of various images processing technique, field survey, and lab analysis of various physical and oceanographic parameters. The diverse steps involved in this project described follows.

A. Digital Image Pre-Processing

The raw satellite images restrain variety of errors in their geometry and radiometry [10]. So, before proceeding process important to rectify the satellite images before starting their interpretation. This naturally involves the initial processing of raw satellite image for correcting geometric distortions, radiometric corrections & calibration and noise removal from the data [11]. This process is also referred as image rectification. Image pre-processing is done before enhancement, manipulation, interpretation and classification of satellite images.

B. Digital Image Enhancement

After completion of geometry and radiometric correction, the image enhancement process is important for image classification. This enhancement process helps to improve the quality of image and its aid to enhance the feature with better quality [12] . There are various techniques are used to enhance features they are color transformation, image fusion, histogram equalization, contrast enhancement, density slicing, spatial filtering, various image ratio like NDVI, TVI, RVI., image stacking [13]. These processes can achieve with the help of image processing software such ENVI/ERDAS [14,15].

C. Digital Image Classification

Digital image classification helps to extract information from satellite image. The multi spectral image mainly used in these processes with the aid of various decisions ruling and grouping of pixel and decision tree [16]. The different features can extract with the process of different classification process. The supervised and unsupervised classification generally used in these classification process, the various subclasses present in these classifications they are parallelepiped, minimum distance, mahalanobis distance, maximum likelihood, spectral angle mapper, spectral information divergence, binary encoding, neural net, ISO data and K-means [17–19]. The various band ratios assist to classify terrain feature without interference and it simply automated. The diverse processing software used to achieve this technique some of them are ENVI and ERDAS. The following equation 1 to 5 shows indices used in this project for classifying various terrain features [11,20,21].

- Normalized Difference Water Index (NDWI) = (Green-NIR) / (Green + NIR) (i)
- Modified Normalized Difference Water Index (MNDWI) = (Green-MIR) / (Green + MIR) (ii)
- Normalized Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red) (iii)
- Normalized Difference Pond Index (NDPI) = (MIR – Green / MIR + Green) (iv)
- Normalized Difference Turbidity Index (NDTI) = (Red – Green) / (Red + Green) (v)

D. Georeferencing and Digitizing Image/Map

The main goal of the Geographic Information System is integrating of available geographic data into other GIS data. In regulate the available GIS data with existing referenced data is called Georeferencing [12]. This process helps to digitize the satellite image in to desired map. The scaling is the main factor in this processing; this procedure can associate with referenced GIS data with none referenced data [11]. By transferring the referenced scale into the other GIS data is the main task in the georeferencing [22].

E. Overlay Analysis

Overlay is the process involved in GIS, these operation helps to combine various layer into single layer, its lend a hand to identify suitable area with desired properties [16]. The allocated level of properties should take as reference in the process for overlay analysis. The various analysis used in the overlay analysis they are wide overlay and region wide or cookie cutter approach [19].

F. Multi Criteria Evaluation

GIS has area to analyse various tasks with the position of spatial and attribute data [14]. Multi Criteria Evaluation is the process determined with the aid of weighted overlay analysis. It's meaning that allocating value to each pixel with the reference of desired properties. The various parameter maps should reference with different numbering and it should analyse with overlay process. MCE models is used to evaluate part of spatial analysis, it's carried on the value of weightage of each sub class with in all parameters thematic map [23]. The value to every pixel gives weightage to every pixels and it only performed in raster map. The weightage normally varied from 1 to 4, where 1 shows the area is not suitable and 2 shows less suitable, 3 indicates moderately suitable and value 4 for highly suitable [16].

4. Pictorial Representation of Various Parameters

The various physical parameters should consider for classify the area which is suitable for collecting various field data. Although GIS proved to be of limited value in this study, it is still recommended that, prior to the establishment of any onshore aquaculture operation, a detailed site assessment is conducted to evaluate at the following parameters:

- Infrastructure facilities
- Saltpan
- Potential for expansion-availability of adjacent area
- Existing aquaculture
- Water bodies
- Conflicting uses of area
- Distance from land
- Waste land
- Settlements
- Area type of soil
- Distance between farms
- Geology and geomorphology

The selection of offshore aquaculture site for cage culture is very important, as success often depends largely on proper site selection [24]. The various parameters consider in selecting sites for offshore aquaculture are the following:

- The depth of the water line should be minimum 5 meters and large scale at 10m to 30m.
- Water feature and transmission should be high-quality, free from local and industrial pollution.
- Sites should be in sheltered bays for fortification from physically powerful winds.

- They should be secure from frequent disturbance from local people.
- There should be access to land and water shipping.
- They should be devoid of algal blooms to evade fouling.
- They should be gratis of aquatic macrophytes and high populations of wild fish.

The different types of parameters maps had been prepared from various GIS analysis, image processing, field survey and ground truthing with the aid of ARC GIS and ENVI software [25]. The diverse physical and oceanographic parameters map helps to delineate the suitable site for onshore and offshore aquaculture after processing various GIS overlay analysis and Multi criteria Evaluation. The different parameters map are Coastal Village Map and Thematic Maps such Settlement Map, Salt Pan Map, Water bodies Map, Waste land Map, Soil Map, Pollution Map, Geomorphology Map, Geology Map, Depth Map, Island Map and Estuary Map are shown in figure 1 to figure 12.

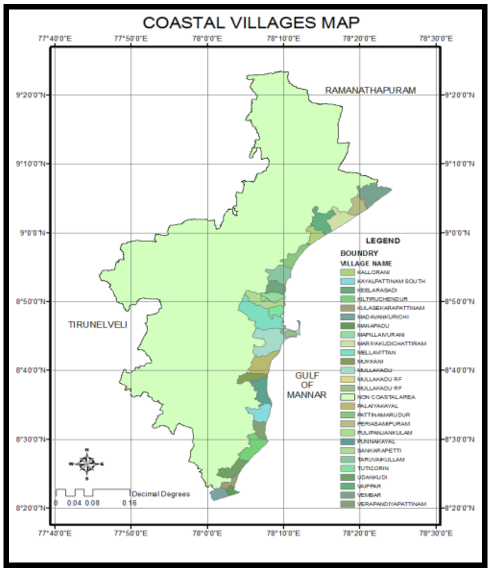

Figure 1: *Coastal Village Map*

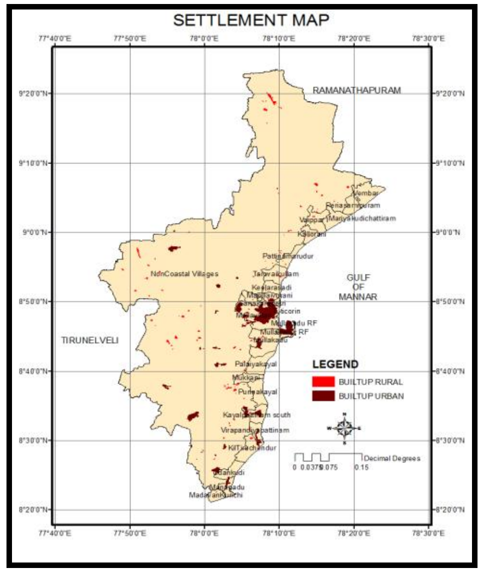

Figure 2: *Settlement Map*

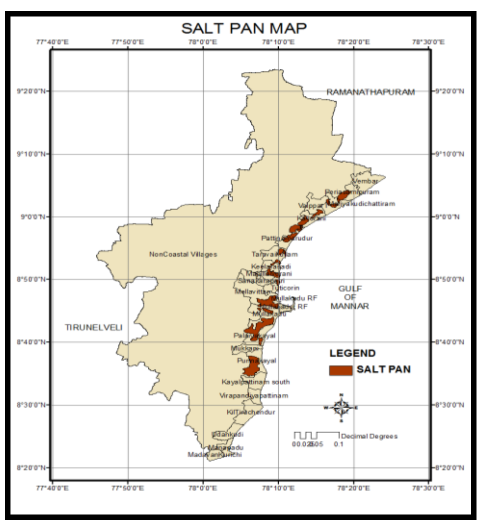

Figure 3: *Salt Pan Map*

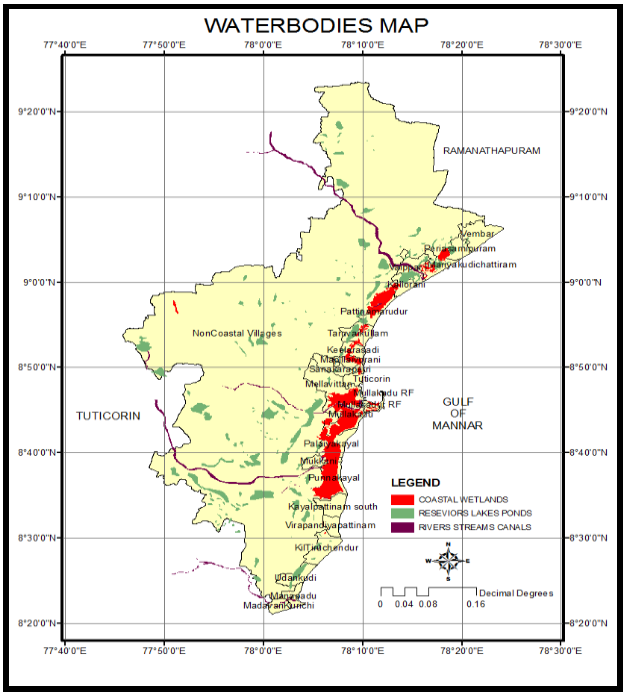

Figure 4: *Water Bodies Map*

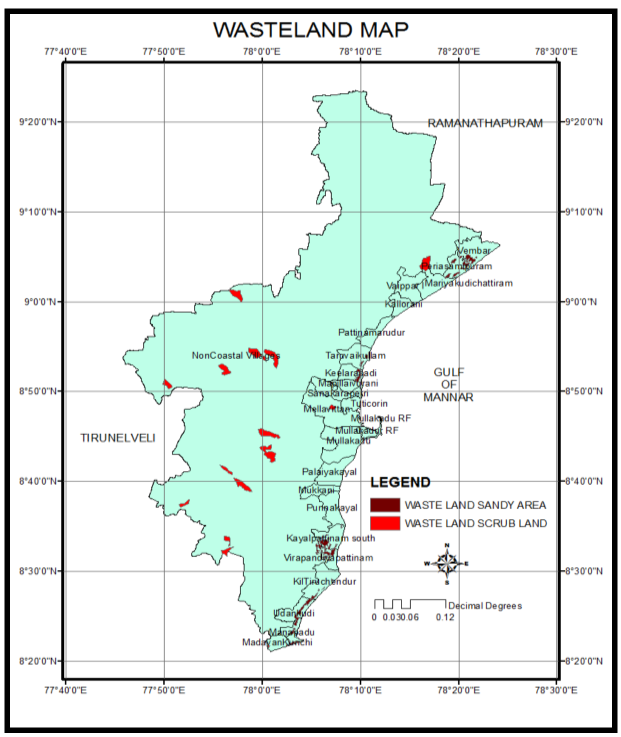

Figure 5: *Waste land Map*

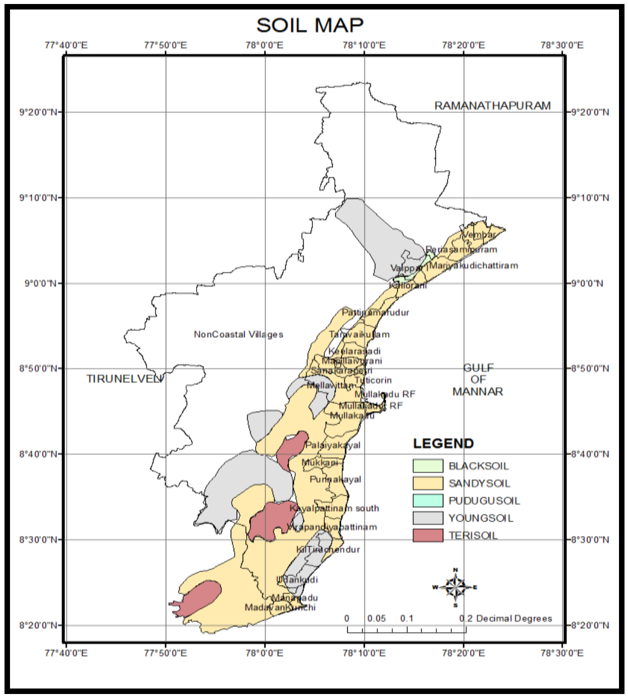

Figure 6: *Soil Map*

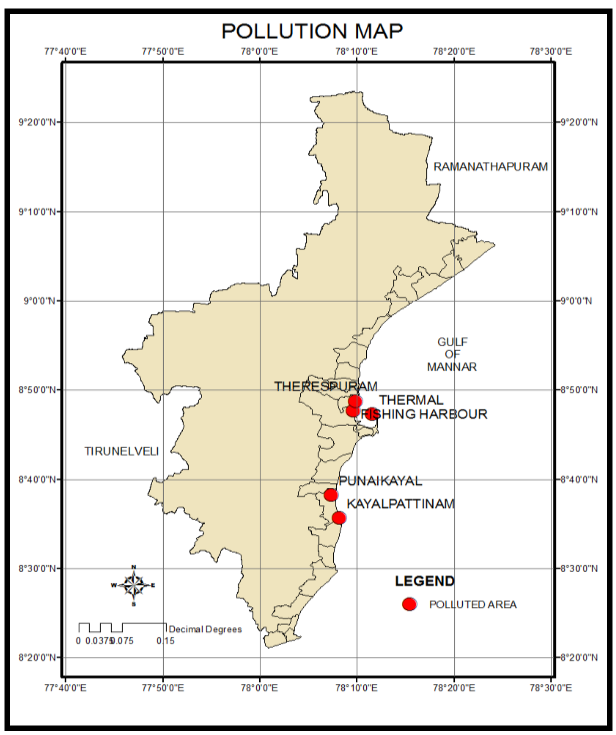

Figure 7: *Pollution Map*

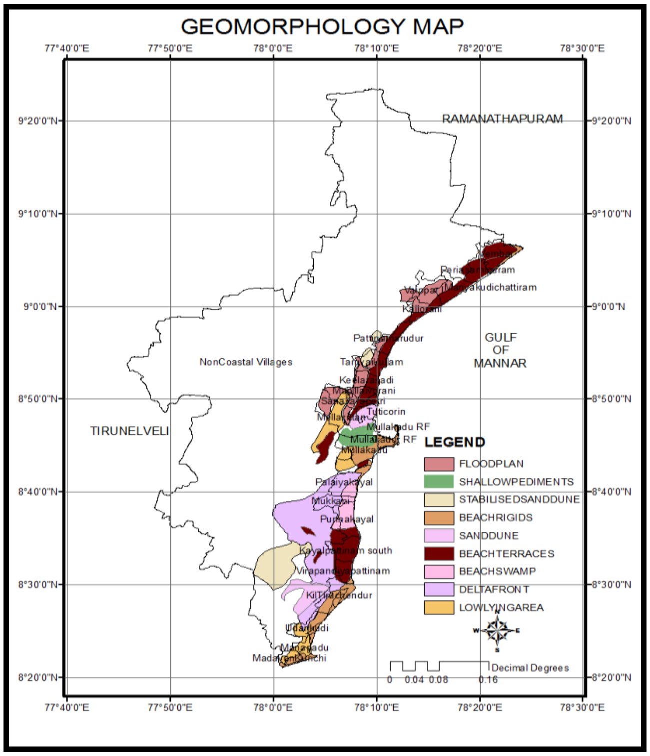

Figure 8: *Geomorphology Map*

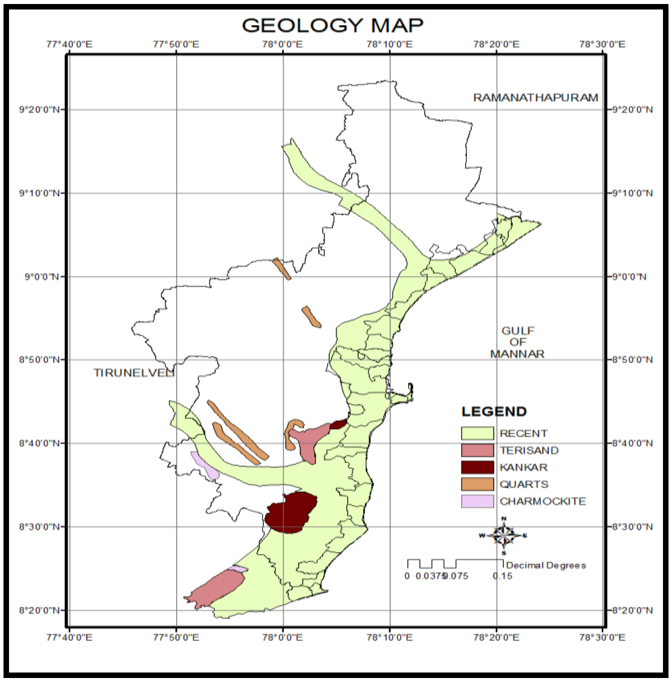

Figure 9: *Geology Map*

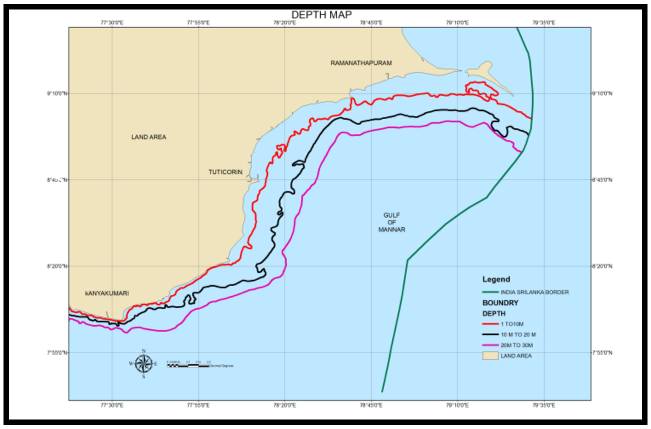

Figure 10: *Depth Map*

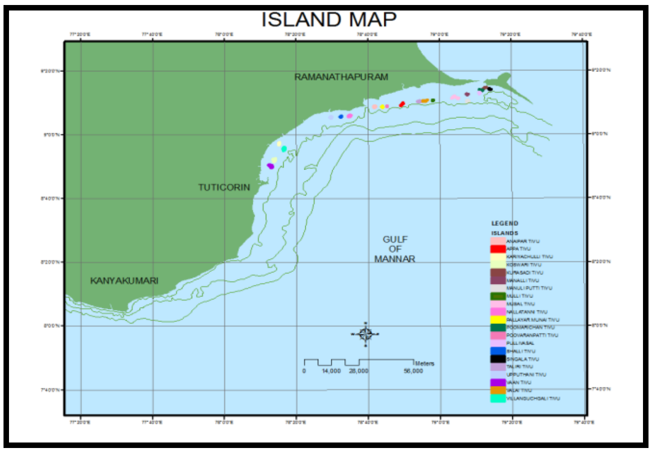

Figure 11: *Island Map*

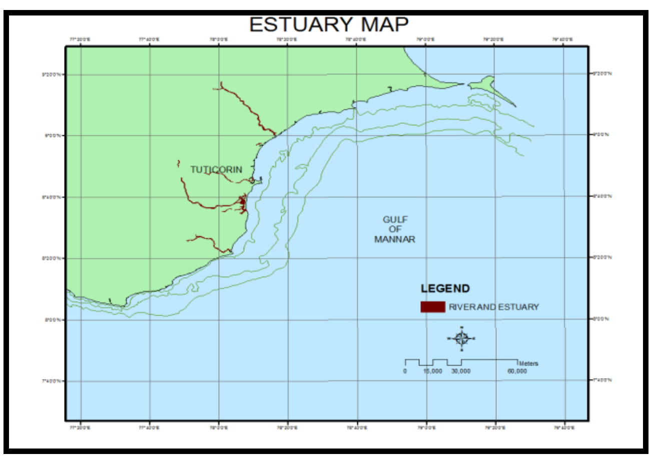

Figure 12: *Estuary Map*

4. Results

A. Pictorial Representation of Aquaculture Selected Site

The Aquaculture suitable site map of Tuticorin Coastal Village shown in figure 13 and figure 14. The suitable site map shows the area which is suitable land and water area for onshore Aquaculture and not suitable area for onshore Aquaculture. The figure 15 shows the suitable area for offshore Aquaculture.

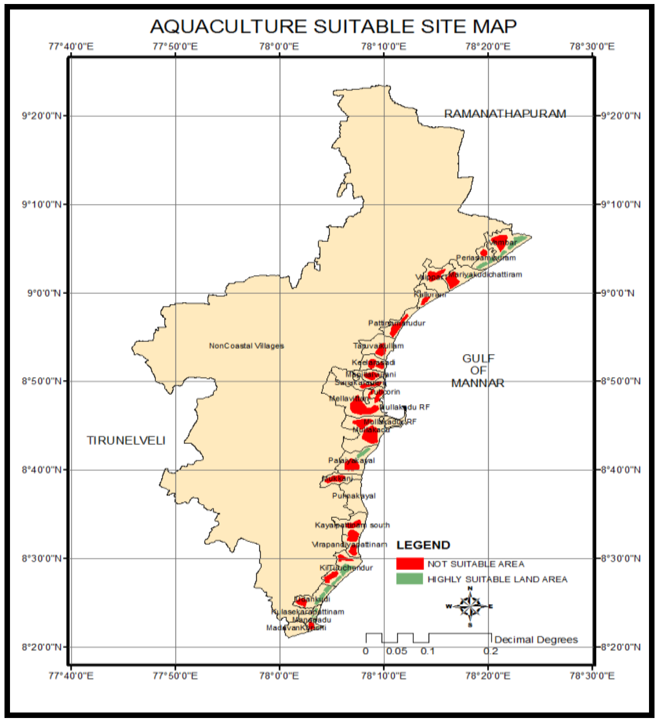

Figure 13: *Aquaculture Suitable Site Map*

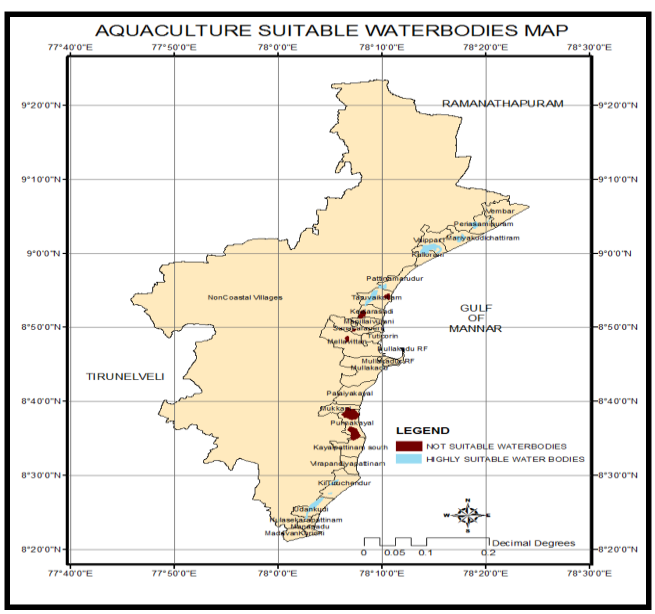

Figure 14: *Aquaculture Suitable Water bodies Map*

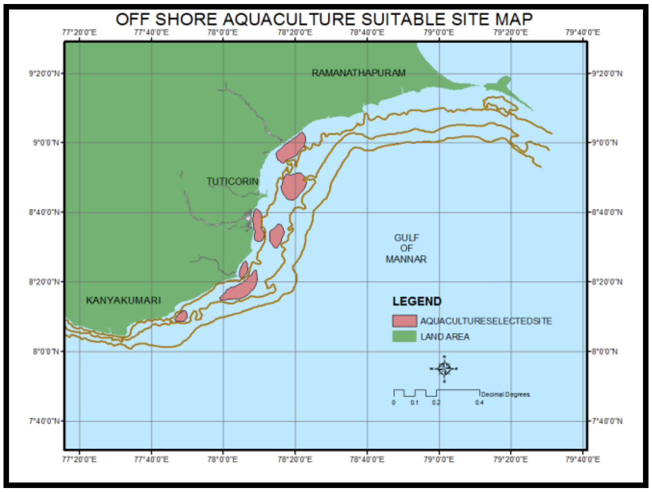

Figure 15: *Offshore Aquaculture Suitable Site Map*

B. Marine Fish Resources Map

The Marine fish resources maps classified by four categories such as Prawn Grounds, Pearl Banks, Cods Bream's Snappers and Fishes and Chanks. The Gulf of mannar majorly presence of Marine fish resources such the pelagic sardines, seer fish, tunas, mackerel, sharks, carangids, barracudas, wolf herring, full and half beaks, the demersal perches such as sweetlips, groupers, rock-cods, snappers, goat fishes, croakers, sharks, rays, skates, coral fishes, prawns and pearl oyster. The figure 15.1 shows the prawn grounds situated in Gulf of Mannar region and figures 16, 17 and 18 illustrates the pearl banks, fishes and chunks beds, cods breams snappers location of Gulf of Mannar.

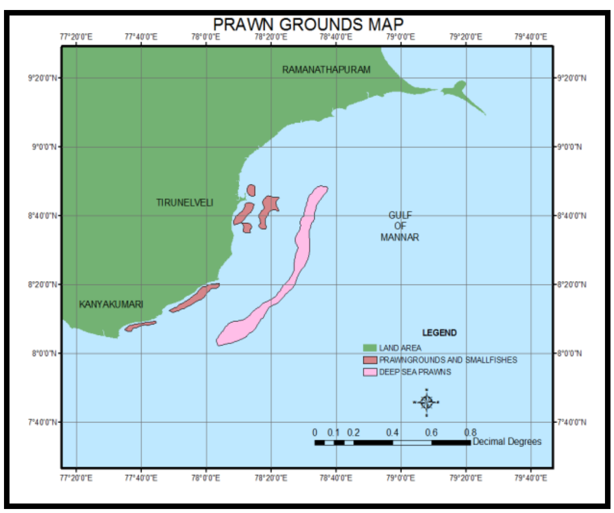

Figure 15.1: *Prawn Ground Map*

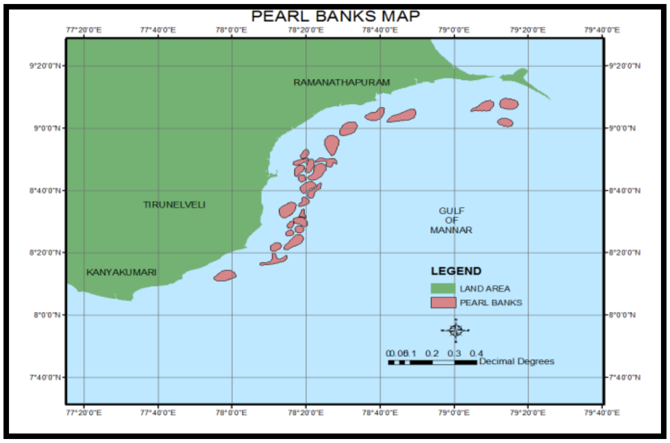

Figure 16: *Pearl Banks Map*

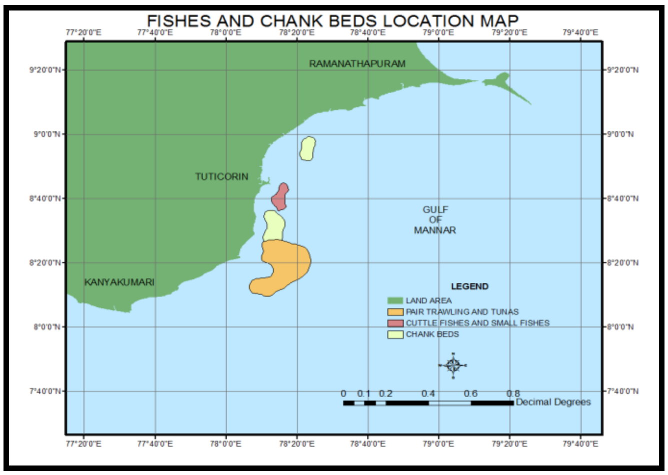

Figure 17: *Fishes and Chank Beds Location Map*

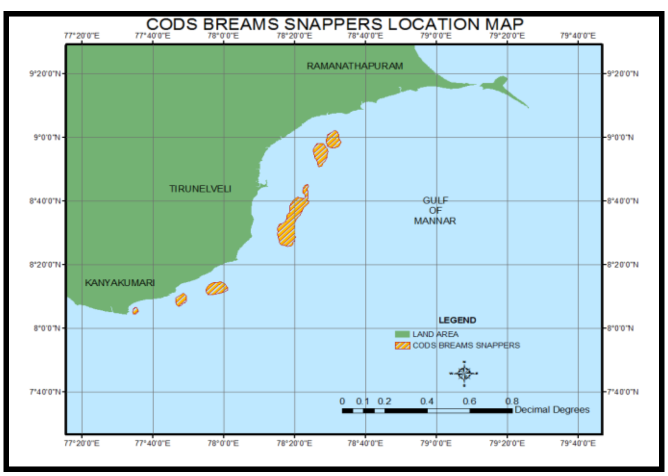

Figure 18: *Cods Breams Snappers Location Map*

5. Conclusion

This project provides information at a regional level that could be used by local fish farmers to select the area and water bodies for Aquaculture activities. Its including offshore and onshore of Tuticorin Coastal area. The Marine Fish Resources System helps to the fisherman to locate the fish resources and it's also aid to research scholar to study about the Marine fish resources in Gulf of Mannar region. For the land suitability analysis based on various physical parameters the different thematic maps are prepared using the statistical data and Remote Sensing data. Using the MCE approach all the layers of thematic maps have undergone weighted overlay analysis. Finally, suitability maps for onshore and offshore aquaculture are derived. It has been also found that the present land-use options can be changed to profitable ones for better economic returns and sustainable resource management. The results demonstrate that the available Remote Sensing satellite data in collaboration with various field survey data can be best utilized for Aquaculture development of an area. Multiple integration options in GIS are of immense use for data integration and overlay analysis to obtain better and faster results in judicious utilization and allocation of natural resources. Because of the GIS analysis it is found that many of the waste land and water bodies and Coastal area are with potential that are capable growing the fish species, crustaceans, mollusces and aquatic plant. Thus, the waste land and water bodies and large amount of coastal area can be cultivated with the aquaculture and cage culture for the best utilization of the land and water.

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Research Article **Open Access**

Mapping and Analysis of Marine Pollution in Tuticorin Coastal Area Using Remote Sensing and GIS

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Abstract In this project, the Marine Pollution Information System has been suggested with the help of Remote Sensing and GIS. This system provides pollution hot spot area and spread rate of the Tuticorin coastal area in Tamilnadu, India. The spread rate and hot spot analysis has been analyzed with the aid of various chemical, biological and physical parameters such as pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia. The Remote Sensing data plays vital role in pollution monitoring and analysis. The Geographic Information System and Remote Sensing facilitate to scrutinize various marine pollution such Industrial pollution, sewage pollution and anthropogenic pollution. The various pollution parameters are examined with the allusion of "General Coastal Cater Quality Standard". The preliminary investigations of pollution spots were identified on the remote sensing data (IRS P6) through the visual interpretation techniques. From the visually interpreted data the major polluted spots were identified on the ground by ground survey method. The water samples were collected from the polluted spots. The various samples had undergone with diverse laboratory analysis and readings were stored in GIS database. The various pollution parameters reading are compared with General Coastal Cater Quality Standard values in GIS environment. The various parameters Map, Hot Spot Map and Spread Rate Map are generated with the assist of Weighted Overlay Analysis and Statistical Analysis in ARC-GIS.
Keywords *Remote Sensing, Geographic Information System, Marine Pollution, Digital Image Processing, Field Survey, Statistical and Overlay Analysis*

1. Introduction

Coastal environment plays a main role in nation's wealth by asset of the resources, productive habitats and rich biodiversity. The term 'pollution' describes the foreword of harmful or artificial substances or product into the environment. Pollution is human activity or natural disasters cause the environment to become contaminated or unclean [1]. Pollution is the introduction by man, directly or indirectly, of substances or energy into the marine environment resulting in deleterious effects of such nature as to endanger human health, harm to living resources ecosystems and hinder marine activities quality of seawater. The marine environment mainly contaminated by waste disposal. The wastes of society can be placed on land or in the water. It also penetrates directly to the marine environments [2].

The coastal areas of Tuticorin are assuming greater importance owing to increasing human population, urbanization and accelerated industrial activities. These anthropogenic activities have put tremendous pressure on the fragile coastal environments [3]. In general, the near shore regions are of great concern now. Coastal pollution in Tuticorin has seriously affected the exploitable living resources, recreational and commercial uses of coastal areas and the overall integrity of the marine and coastal ecosystems. Hence protection of the coastal and marine regions from continuing pollution becomes the most essential in coastal resources management [4]. Effective planning for controlling and combating coastal pollution requires knowledge about the magnitude of the pollution, the entry, transport and the state of pollutants in the marine environment and their effects on marine ecosystems [5].

2. Study Area and Description

Tuticorin coast has a major port and it is rapidly developing area. The study area falls in the latitudinal and longitudinal extensions of 8°40’- 8°55’ N and 78°0’ -78°15’ E on the Tamil Nadu; India has a coastline of about 7,500 kms. The coastline of Tuticorin has a length of about 163.5 kms. Tuticorin is port town with several industries and saltpan activity, its population is around 0.4 million. The town generates an estimated 17.5 MLD of sewage. There are no treatment facilities for the sewage; all of it is disposed of in canals that eventually reach the sea. Industries around Tuticorin include a refinery, aquaculture, chemicals and fertilizers, caustic soda and a thermal power plant. The total volume of waste discharge from these industries, other than aquaculture is about 10.4 MLD [1]. The effluent characteristics from these industries include suspended solids, ammonia, nitrate, BOD compounds, oil and grease, and trace quantities of heavy metals such as chromium. Municipal waste contains high BOD compounds (putrefied organic matter), nutrients and bacteria. Aquaculture generates about 91.2 MLD [6]. Major Industries such as Southern Petrochemical Industrial Corporation, Thermal Power Plant, Tuticorin Alkali Chemicals and Heavy Water Plant are also present in this area. Due to the accelerated development activities the coastal area experience significant changes [3].

3. Methodology

Remote Sensing & Geographical Information System (GIS) is the backbone for marine pollution mapping and analysis [7]. It integrate a large range of spatial and non spatial information with respect to topography & other spatial information including existing data of physical, chemical and biological [8]. With the help of satellite based map and digital information all the required information are integrated in the GIS based pollution mapping system [9]. It has four steps for mapping and analysis spatial variations of marine pollution; they are Data collection, Digital Image Processing, Laboratory Analysis Geographic Information Systems (GIS) Analyzing and Map generation. The figure 1 shows the work flow of Mapping and Analysis of Marine Pollution.

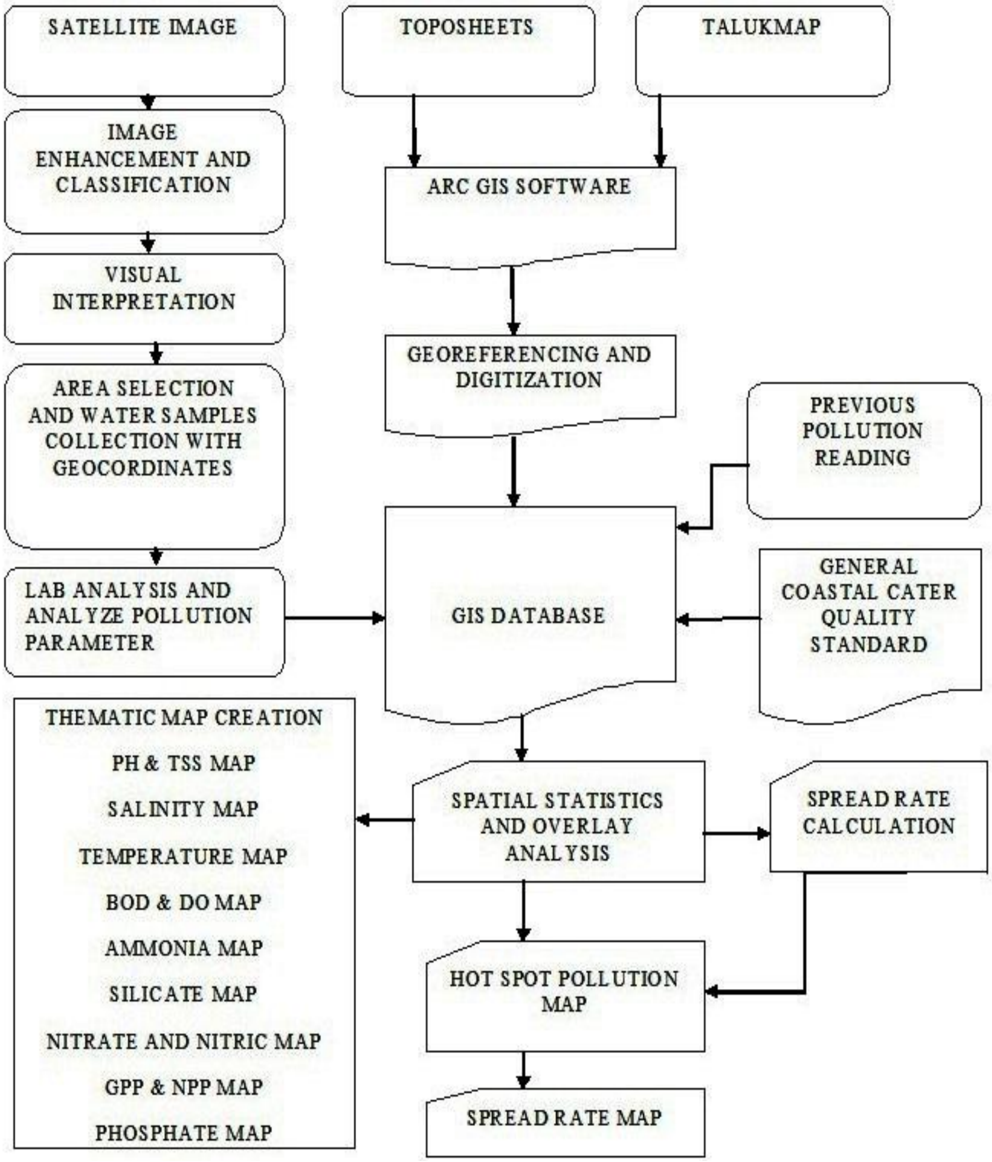

Figure 1: *Flow Chart for Mapping and Analysis of Marine Pollution*

A. Data Collection

The data required for the mapping and analysis of marine pollution obtained from remote sensing satellite image, toposheets and existing water quality values. The satellite data used to geo-referencing the toposheet to the real world coordinate system and identify the area of pollution point source like thermal power plant, harbor, fishing harbor, chemical factory, outlet of sewage and tourism and urbanization area through the visual interpretation. Toposheet furnish the reference map for the pollution mapping. The existing water quality value used for finding the spread rate of pollution.

B. Digital Image Processing

It is software based image classification technique which involves automated information extraction and subsequent classification of multispectral satellite images [10]. These are statistical decision rules which groups pixels in different feature classes [11]. Digital classification techniques are less time consuming than visual techniques.

C. Visual Interpretation

Interpretation is the processes of detection, identification, description and assessment of significant of an object and pattern imaged. The method of interpretation may be either visual or digital or combination of both. Both the interpretation techniques analysis the output is also visually analyzed. The ability to recognize objects in aerial and satellite photographs [12]. From knowledge of a landscape and its interpretation keys, the interpretation rules keys such as color, form, size, texture or context.

D. Identify the Area to Be Measured

The area of point and non-point source of pollution like thermal power plant, harbor, fishing harbor, chemical factory, outlet of sewage and tourism and urbanization area identified and fixing the pollution station on area through the visual interpretation.

E. Taking GPS Reading on Station

The area identified for pollution station through the visual interpretation on satellite image and ground truthing. In ground truthing taking the GPS points on each pollution stations like thermal power plant, harbor, fishing harbor, chemical factory and outlet of sewage. That GPS data is used as input for the Georeferencing and Rectification.

F. Collecting Water Samples

Collecting Water Samples in each pollution station like thermal power plant, harbor, fishing harbor, chemical factory and outlet of sewage. Water samples are collected through the field survey with the GPS instrument.

G. Measure Pollution Parameters

After the collection of the water sample the following parameters are measured with the aid of Laboratory analysis, pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia [1]. The measured qualities are stored in GIS database.

H. Layer Creation

For each water samples physical, chemical, biological parameters spatial layers are created using GIS software and they are pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia.

I. General Coastal Cater Quality Standards

The general coastal water quality standards for several parameters of National Environmental Board report, 1994. It has standard value for various physical, chemical and biological parameters from the water. The water quality value exceed the limits mean the pollution present in the water [1]. The table 1 shows the Coastal Cater Quality Standard value for various parameters.

Table 1: *Coastal Cater Quality Standard Value Table*

Parameters	Standards
pH	7.8 – 8.3
Temperature (◦C)	30
Total Suspended Sediments (TSS)	25 mg L^{-1} or less
Dissolved Oxygen (DO)	4mg L^{-1} or more
Biochemical Oxygen Demand (BOD)	30 mg L^{-1} or less
Nitrate	10 mg L^{-1} or less
Total Nitrogen	1 mg L^{-1} or less
Phosphorus as Phosphate PO4	0.1 mg L^{-1} or less
Chlorophyll-a	15 mg L^{-1} or less

J. Calculate Spread Rate

Spread rate can be found from the existing water quality value of successive measurements. Standard deviations of water quality value were calculated. This is used for generate the future spread rate map (8).

K. Spatial Statistics / Overlay Analysis

One basic way to create or identify spatial relationships is through the process of spatial overlay [13]. Spatial overlay is accomplished by joining and viewing together separate data sets that share all or part of the same area. The result of this combination is a new data set that identifies the spatial relationships. Finally a hot spot pollution area was determined by performing a weighted average of the all separate layer of parameter to create the hot spot pollution map of Tuticorin coastal area.

4. Results

In this project different Maps have been prepared for various analysis and parameters such as pH Map, Atmospheric Temperature Map, Surface Temperature Map, Total Suspended Sediments Map, Chlorophyll 'a' Map, Dissolved Oxygen Map, Biochemical Oxygen Demand Map, Net primary productivity Map, Grass primary productivity Map, Nitrate Map, Nitrite Map, Phosphate Map, Silicate Map, and Ammonia Map. The figure 2 to 15 shows the various parameters map and figure 16 and 17 shows the Pollution Hot Spot Map and Spread Rate Map respectively. The figure 18 and 19 illustrate Marine Pollution Information System portal.

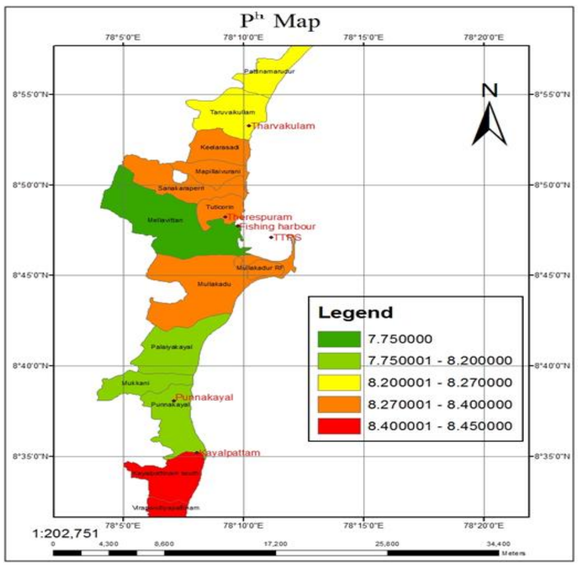

***Figure 2**: pH Map*

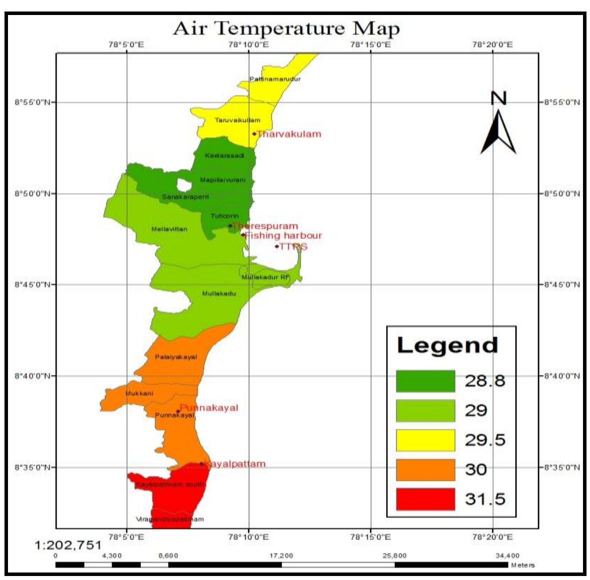

***Figure 3:** Air Temperature Map*

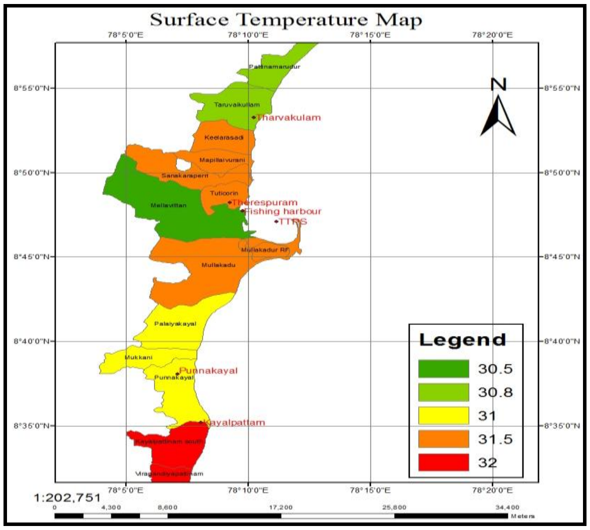

***Figure 4**: Surface Temperature Map*

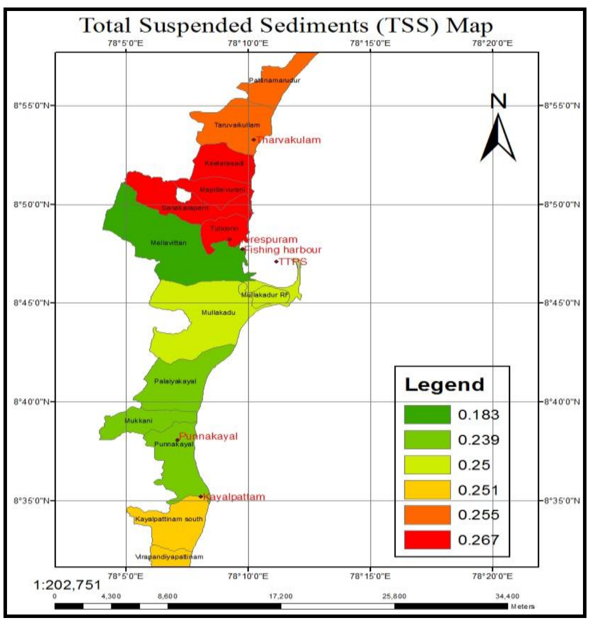

***Figure 5:** Total Suspended Sediments Map*

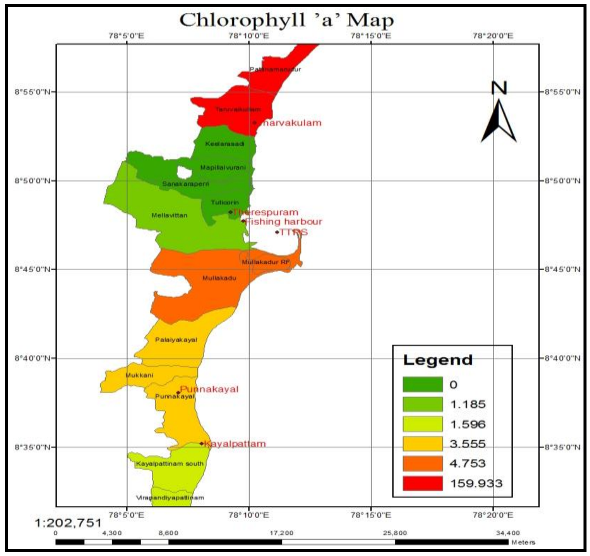

Figure 6: *Chlorophyll 'a' Map*

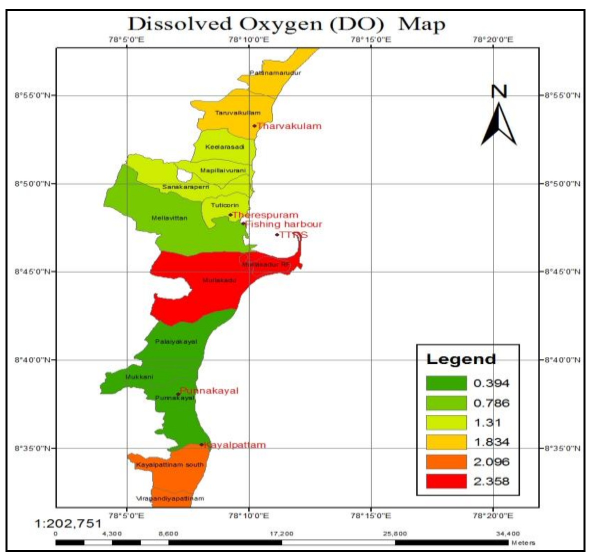

Figure 7: *Dissolved Oxygen Map*

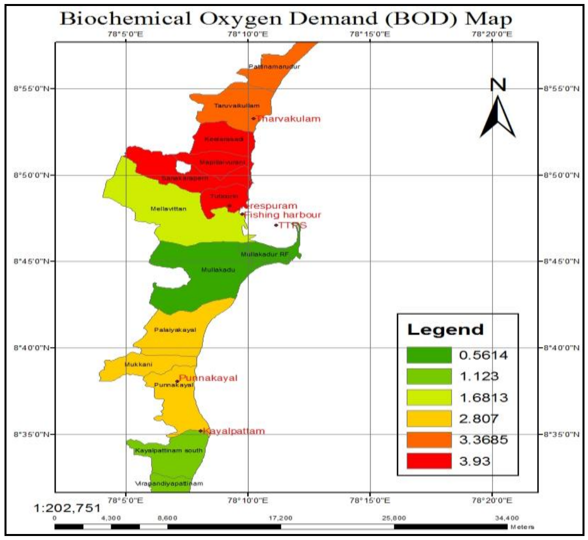

Figure 8: *Biochemical Oxygen Demand Map*

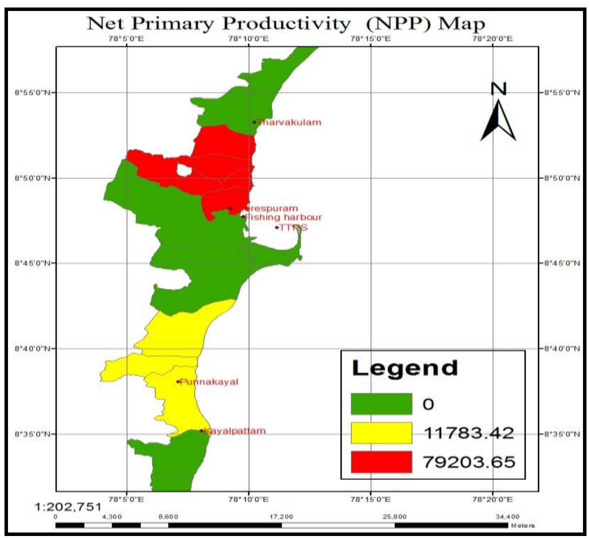

Figure 9: *Net Primary Productivity Map*

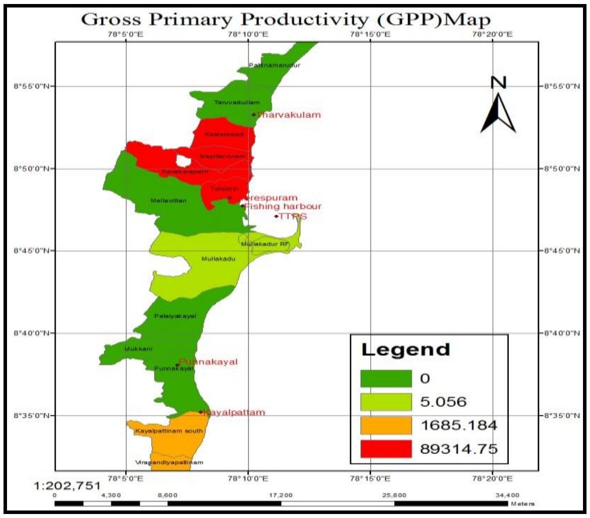

Figure 10: *Gross Primary Productivity Map*

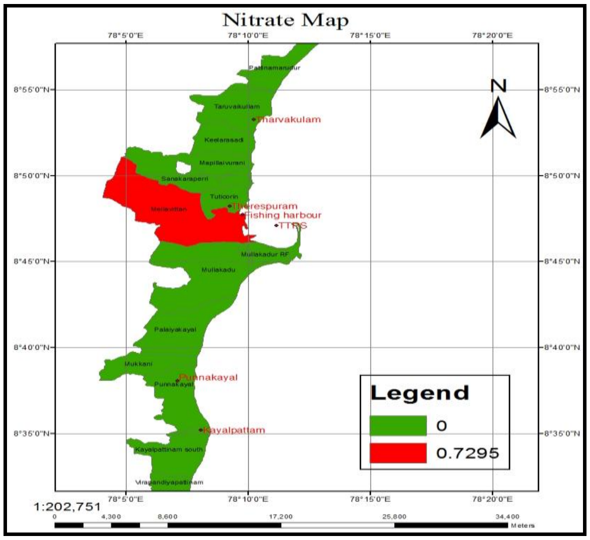

Figure 11: *Nitrate Map*

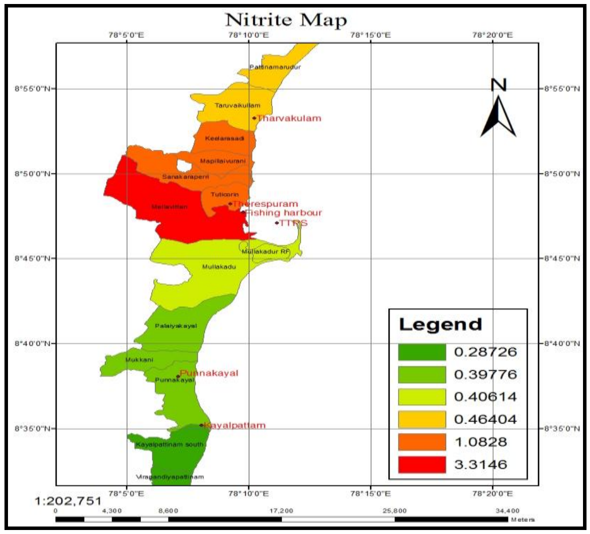

Figure 12: *Nitrite Map*

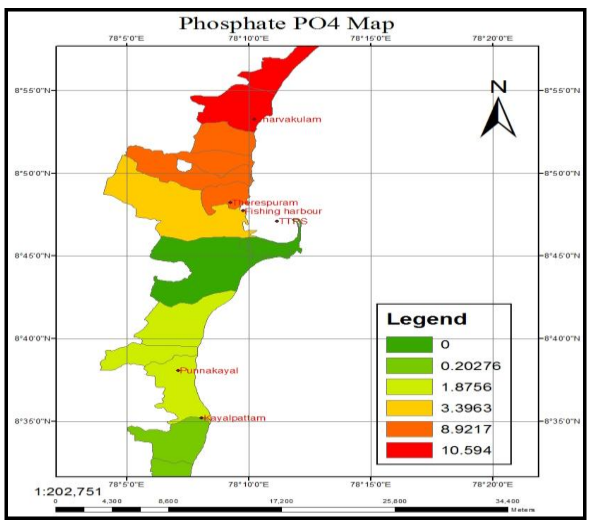

Figure 13: *Phosphate Map*

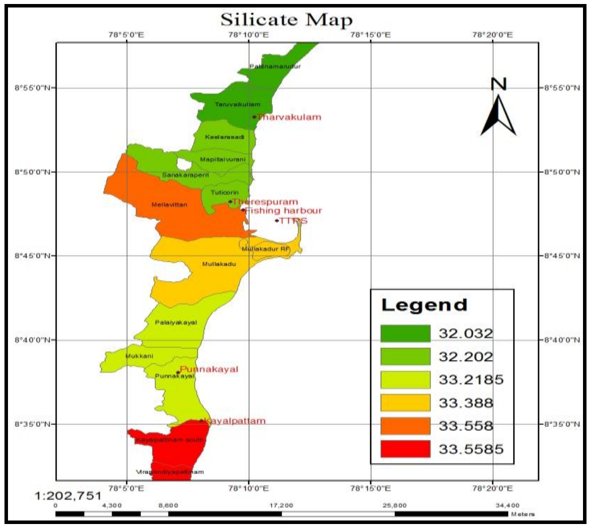

Figure 14: Silicate Map

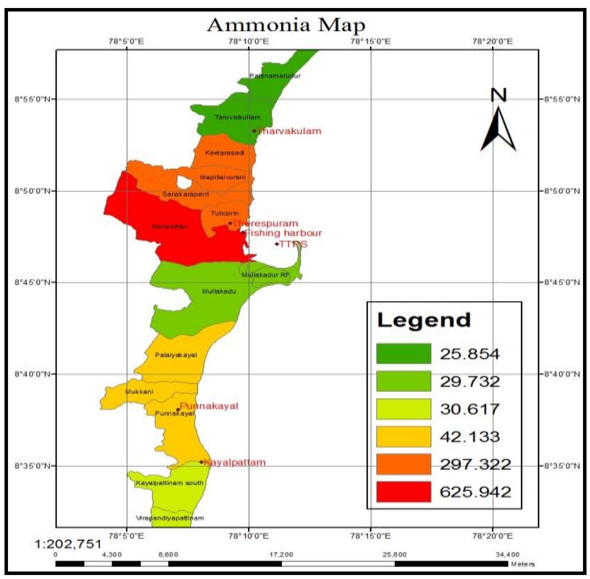

***Figure 15**: Ammonia Map*

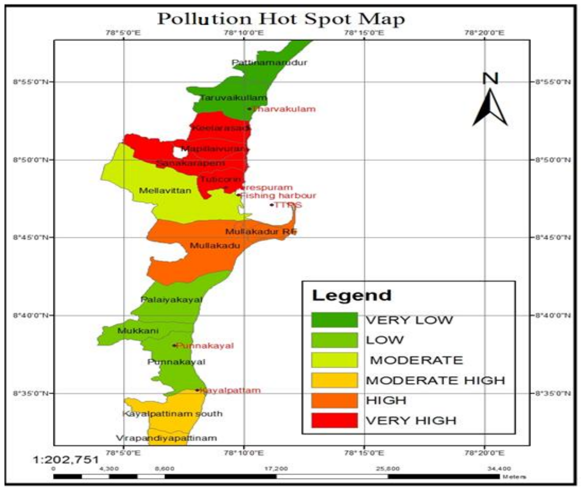

Figure 16: *Pollution Hot Spot Map*

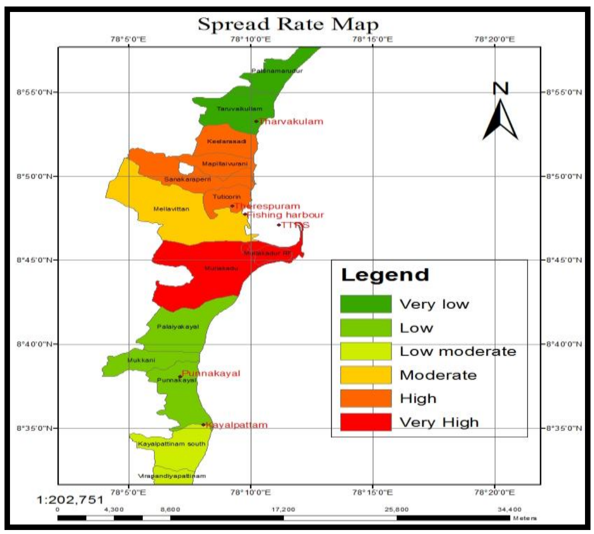

Figure 17: *Spread Rate Map*

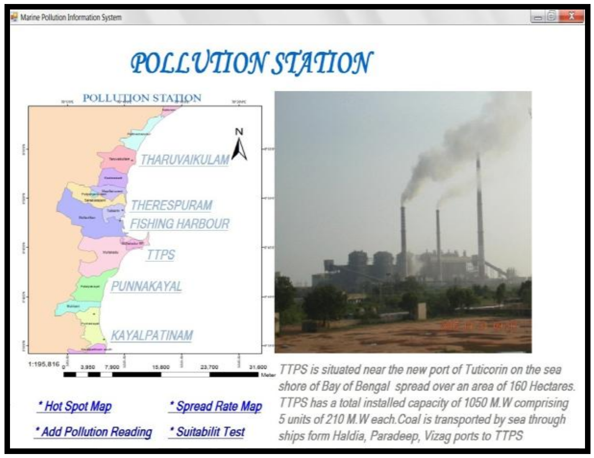

Figure 18: *Marine Pollution Information System Portal Snap shot*

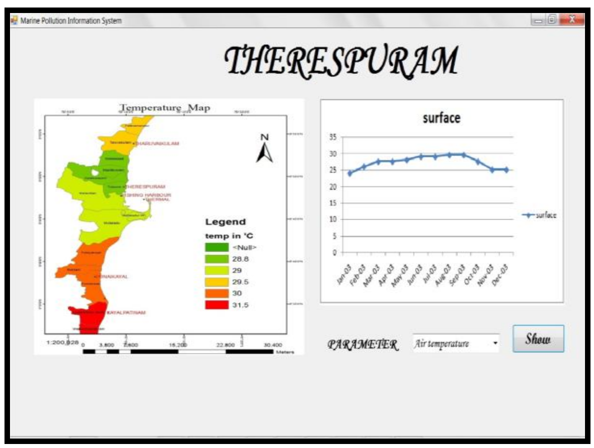

Figure 19: *Marine Pollution Information System Portal Snap shot*

5. Conclusion

This project provides Marine pollution information at a provincial level that could be used by Research people, Local community and fisher folks. It gives the warning system for marine pollution in different coastal areas in Tuticorin. For the hot spot analysis based on various Physical, chemical and biological parameter maps are prepared using the statistical data and Remote Sensing data with the help of GIS environment. Using the General Coastal Cater Quality Standards approach on all the layers of thematic maps has undergone weighted overlay analysis.

Hot spot map and Spread rate map were derived with the assist of GIS analysis. In that Therespuram and Tuticorin thermal power station (TTPS) have high rate of pollution and it seems that polluted area are not suitable for living organisms. Kayalpatinam have reasonable value of pollution. Fishing harbor and Punnakayal have highly moderate rate of pollution and these areas are quite suitable for living organisms. Finally Tharuvaikulam has low pollution value and it clearly shows that the area is greatly suitable for living organisms.

From Spread rate map, Tuticorin thermal power station (TTPS) has very elevated spread rate of pollution hence the control measure should be taken by introducing chimney (flue-gas stack) of height upto 400 meters or more and proper air filter mechanism should be installed and suggested to increase the cooling tower efficiency. Therespuram has high spread rate of pollution and it has been recommended to remove the wastage from anthropogenic activity and link the sewage into deep sea minimum depth of 20 m and above through pipe line after primary treatment. Kayalpatinam has sensible spread rate of pollution for the reason that DCW chemical factory influenced; the wastage from the chemical factory should dispose into deep sea (20 m) through pipe line after most important treatment is advisable.

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