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Research Article **Open Access**

Land Use and Land Cover Mapping and Shore Line Changes Studies in Tuticorin Coastal Area Using Remote Sensing

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Abstract In this project, Land use and Land cover and shoreline studies has been carried out using Remote Sensing (RS) and Geographical Information System (GIS). It is robustly linked to the eco-environment and socio-economic value consign to coastal components. Probable vary to these values will aid in the selection and interpretation of apparent responses to the changing boundary conditions such as human interference and other climatic changes. The results of the risk studies will be very useful in integrated coastal zone management plan. The present work has been carried out with a view to calculate the shoreline change over years to know the high and low sensitive areas. Both conventional and remotely sensed data are used and analyzed through the modelling technique. The present study is aimed to investigate the following four parameters namely; Land use and Land cover changes, Shoreline changes over the years, Geomorphology, Geology using Remote Sensing and GIS techniques. The proposed project aims to assess the changes along the coastal area occurred due to natural causes such as shoreline change due to acceleration and erosion and to identify the Geomorphology of the coastal areas with the aid of Remote Sensing and GIS. The Resultant map products are displayed using VB.NET and SQLSERVER software. These various studies achieved with the processing of IRS p6 LISS 3 and LISS IV satellite data.
Keywords *Remote Sensing, Geographic Information System, Digital Image Classification, Field Survey, GIS Analysis*, *Coastal Vulnerability Index.*

1. Introduction

Coastal zone is a broad transitional area between the land and sea where the waters of the seas meet the land are indeed unique places in our global geography [1]. The shoreline is a boundary line between land and sea. A nation should have adequate information on its natural resources as well as many interrelated aspects of its activities for decision making. Coastal landforms and wetlands are a few of such resources which have acquired importance as they influence various developmental activities along the coastal regions [2]. The coastal region mainly affected by the cause of wind, tidal current, wave and human factors [3]. So the management of coastal region should consider in better way and efficient. The various physical and topological parameters should maintain and observe periodically. In this paper various element such Geology, Geomorphology, Soil are classified and analysed with the help of GIS and Remote Sensing. The different land cover and land use features such built up urban, built up rural, wet land water bodies, waste land, agriculture, salt affected area are extract from remote sensing data [4,5]. For the shore line changes the period of 1998 to 2009 remote sensing data and statistical data of acceleration and erosion are considered in this paper.

2. Study Area and Description

The study area chosen for the present study is a Tuticorin district coastal area in Tamilnadu, India has a coastline of about 7,500 km. Gulf of Mannar extends from Tuticorin to Rameswaram Island in the SW-NE direction, lies between 78º5' & 79º30' E longitudes and 8º47' & 9º15' N latitudes, to a length of about 140 km [6]. Gulf of Mannar is endowed with a rich variety of marine organisms because its biosphere includes ecosystems of coral reefs, rocky shores, sandy beaches, mud flats, estuaries, mangrove forests, seaweed stretches and sea grass beds. A port town Tuticorin with several industries and saltpan activity, its population is around 0.4 million. The coastline of Tuticorin has a length of about 163.5 km – 25 km wide. Major Industries such as Southern Petrochemical Industrial Corporation, Thermal Power Plant, Tuticorin Alkali Chemicals and Heavy Water Plant are also present in this area [5]. Due to the accelerated development activities the coastal area experience significant changes.

2.1. Data Description

The coastal studies of large volume of spatial data require computer based systems like GIS which can be used for solving complex problem. The images of remotely sensed data were also processed for the analysis. The detailed description of the data used has been discussed in this chapter.

A. Topographic Map

A topographic map is a kind of map categorized by large-scale aspect and quantitative illustration of relief, usually using contour lines in modern mapping [7]. A contour line is a grouping of two line sector that join but do not overlap; these symbolize elevation on a topographic map. 1:250,000 scale topographic map used in this project. Conventional descriptions require a topographic map to show both natural and non-natural features [8]. A topographic map is typically available as a map series, made up of two or more map sheets that combine to form the whole map.

B. Remote Sensing Data

The IRS-P6 (Indian Remote Sensing Satellite) LISS III (Linear Imaging Self Scanning Sensor-3) multispectral data covers the study area has been obtained from National Remote Sensing Centre (NRSC), Hyderabad, India [9]. The false colour composite made of NIR (Near Infrared), red and green bands coded with red, green and blue colours respectively [10]. The general characteristics of IRS-P6 are

- Launched into an 817 km polar Sun Synchronous Orbit
- Systematic acquisition of data by IRS-P6 began in January 2005
- IRS-P6 carries three cameras
- Three sensors are LISS-IV, LISS-III, Advanced Wide Field Sensor (A WIFS)

3. Methodology

This chapter deals with the acquisition of data, statistical analysis of data and assessment of shoreline change along the coastal area. Here the thematic layer generations are done along the coastal area with the assess of GIS. The output images are displayed using vb.net for better visualization. The main streams of this work flow are image processing, classification, Field Survey and GIS analysis. The Coastal Vulnerability Index calculated with help of GIS analysis in consideration of eco- geophysical parameter, the parameters are analysed individually and it should be undergone with overlay analysis [5]. The shore line variation mainly analysed with the level of acceleration and erosion rate over the period. The classification of various terrain features accomplish with the level of indices calculation, segmentation, grouping of pixels and classification [11]. The ENVI/ERDAS software is used in the project for image processing technique [12]. The figure 1 shows the flow chart for Coastal and Shore line Mapping.

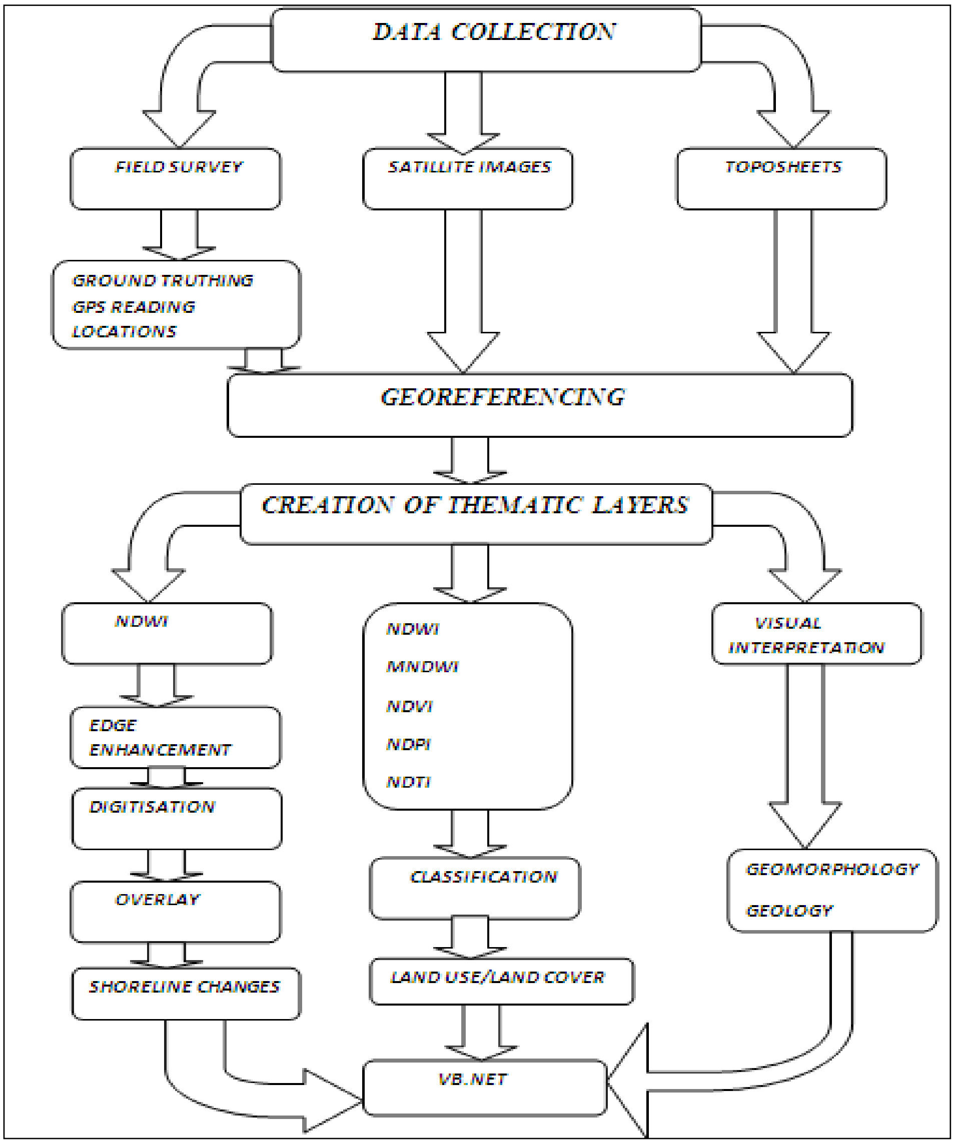

Figure 1: *Flow Chart for Coastal and Shoreline Mapping*

A. Digital Image Processing

The coastal land use and land cover features has derives based on three kind namely, classification, segmentation and grouping [13]. For classification, the supervised and unsupervised classification, various statistical, tonal and textural parameters should consider for classifying different features in the terrain [14]. The feature set contains various classes which include river, tanks, swale, and saltpan, salt affected land with scrub, mudflat, beach ridges, and vegetation, urban and rural built up areas, these are classified with the aid of segmentation and grouping, the various terrain features. These are detected with the combination of Normalised Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Normalised Difference Pond Index (NDPI), Normalised Difference Turbidity Index (NDTI) and Normalised Difference Vegetation Index (NDVI) [15–17].

B. GIS Analysis

In this project various GIS analysis are used such Analysis of Spatial and Attribute Data are overlay analysis, Neighborhood function, Point-in-Polygon and Line-in-Polygon, Topological overlay, Topographic Functions, Thiessen Polygons and Interpolation [18]. GIS analysis mainly helped in finding of shore line changes. The shore line should analyse very infinitesimal, this task can be achieved by the ARC GIS software [19]. The CVI was calculated as the square root of the product of the ranked variables divided by the total number of variables [15]. The Coastal Vulnerability Index (CVI) calculated with the help of various parameters such as follows:

- Land use and land cover changes
- Shoreline changes over the years
- Rate of erosion and acceleration
- Sediment transport
- Geomorphology
- Coastal slope

4. Results

The Coastal Shoreline Change Map and Thematic Maps such as Geomorphology Map, Land Use and Land Cover Map, Geology Map, Soil Map had been prepared with the help of various processing technique and GIS analysis. The coastal processes in Tuticorin coastal area, the shoreline change, land use and land cover, geology, soil and coastal geomorphology were analysed using Remote Sensing and GIS tools. The changes observed at Tuticorin using temporal satellite imageries show that the shoreline dynamics is natural and this is not due to human interference. Coastal processes play a major role in shaping the coastal configuration of this area. The integrative approach using Remote Sensing and GIS tools clearly illustrates both the cause and reasons for the shoreline change. The results of this study will be more useful for shoreline management.

A. Coastal Village Map

The Tuticorin district covers 8 Taluks such as Sathankulam, Tiruchendur, Srivaikundam, Tuticorin, Otapiddaram, Vilathikulam, Ittaiyapuram and Kovilpatti. There are 480 Revenue villages presented in Tuicorin district. This project majorly covers 5 Taluks which comes under Coastal region, such as Tiruchendur, Srivaikundam, Tuitocrin, Ottapidaram and Vilathikulam. There are 26 coastal villages presented in various Taluks of Tuticorin such as Vembar, Periasamipuram, Mariyakudichattiram, Vaippar I, Kallorani, Pattinamaradur, Taruvaikullam, Keelarasadi, Mapillaivurani, Pulipanjankulam, Sanakaraperri, Tuticorin, Mellavittan, Mullakadu Reserved Forest I, Mullakadu Reserved Forest II, Mullakadu, Palaikayal, Mukkani, Punnakayal, Kayalpattinam South, Virapandiyapattinam, Tiruchendur, Udankudi, Kulasekerapattinam, Manapadu and Madavankurichi. The figure 2 shows the coastal village map.

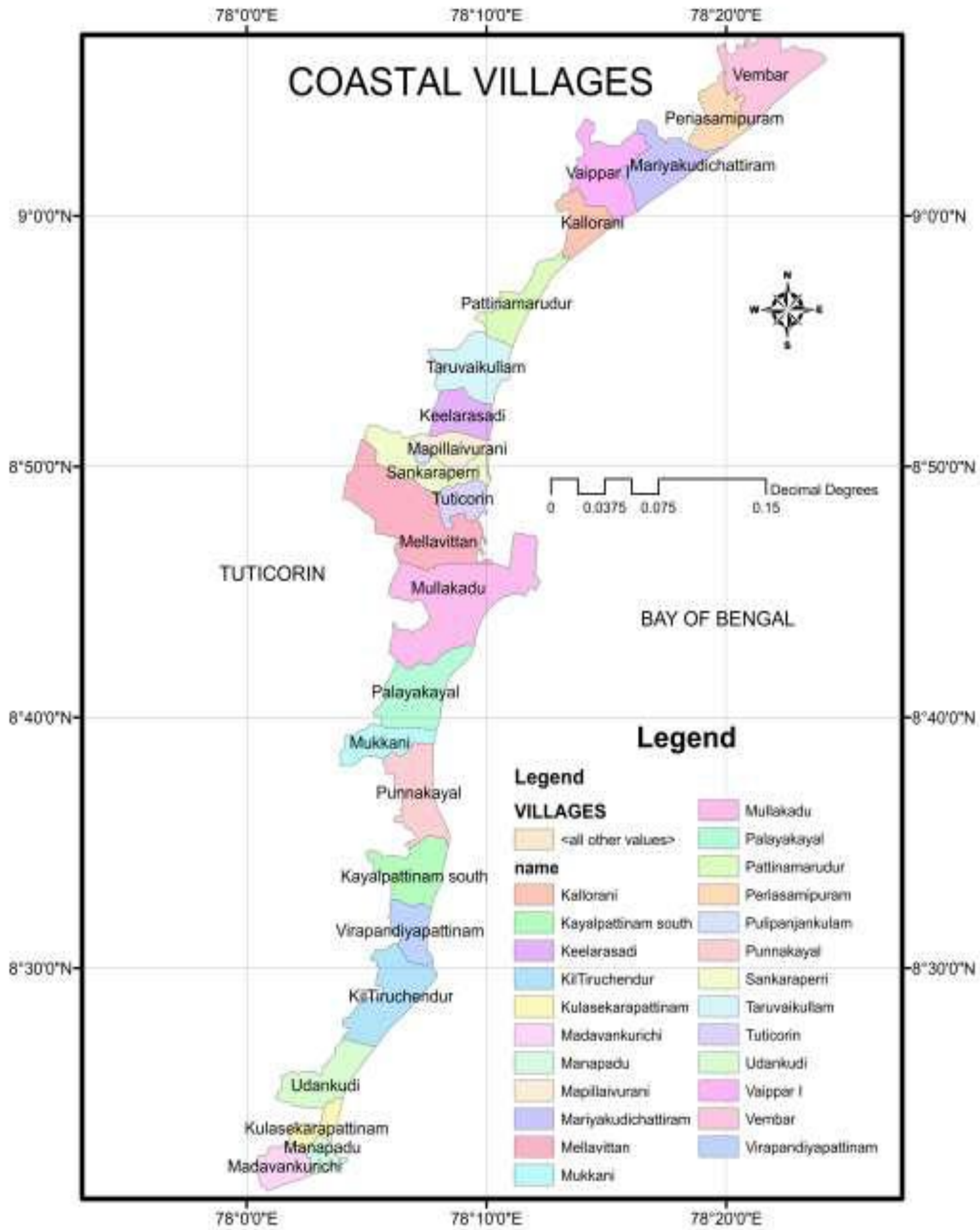

Figure 2: *Coastal Villages Map*

B. Shoreline Maps

The Gulf of Mannar shorelines of 1998 and 2009 are shown in figure 3 and figure 4. The figure 5 shows the shore line changes map. It's clearly shows the changes in shore along Gulf of Mannar.

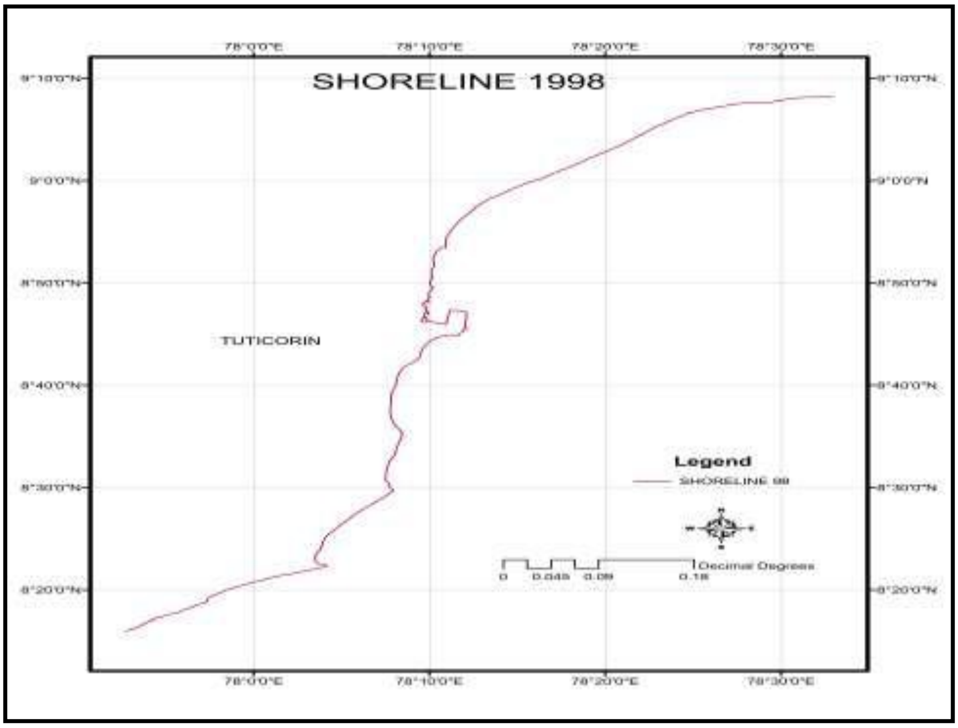

Figure 3*: Gulf of Mannar Shore Line of 1998*

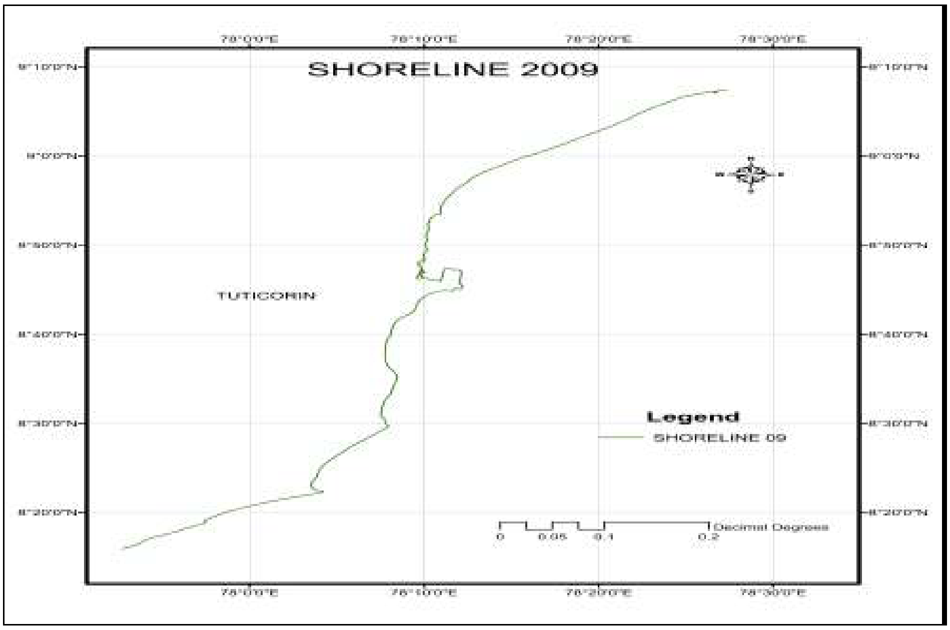

Figure 4: *Gulf of Mannar Shore Line of 2009*

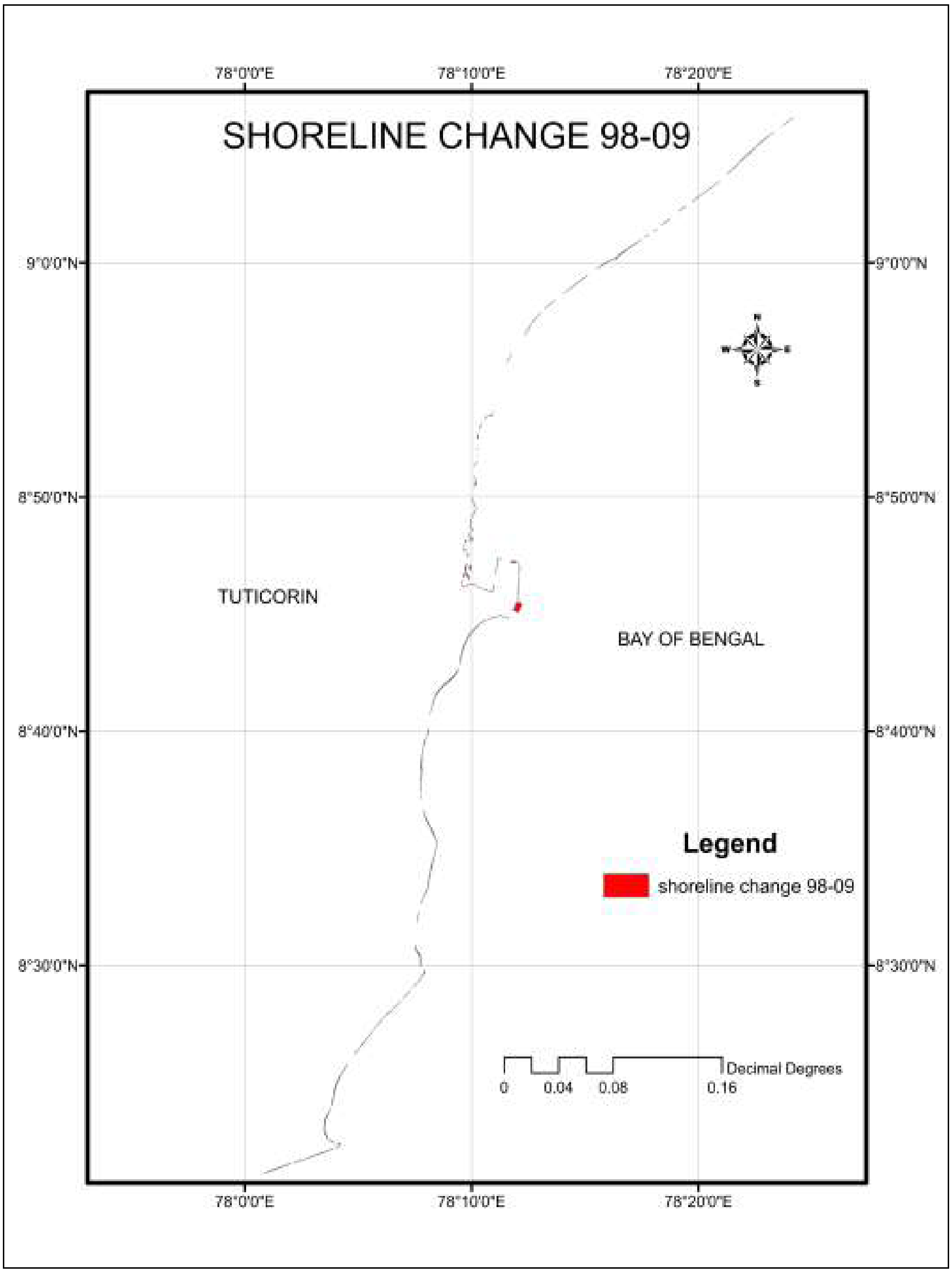

Figure 5: *Shoreline Change Map*

C. Geomorphology Map

The Geomorphology Map of Tuticorin district is shown in figure 6. This map clearly classified as Flood Plan, Shallow Pediments, Stabilized Sand Dune, Beach Rigids, Sand Dune, Beach Terraces, Beach Swamp, Delta Front and Low Lying area.

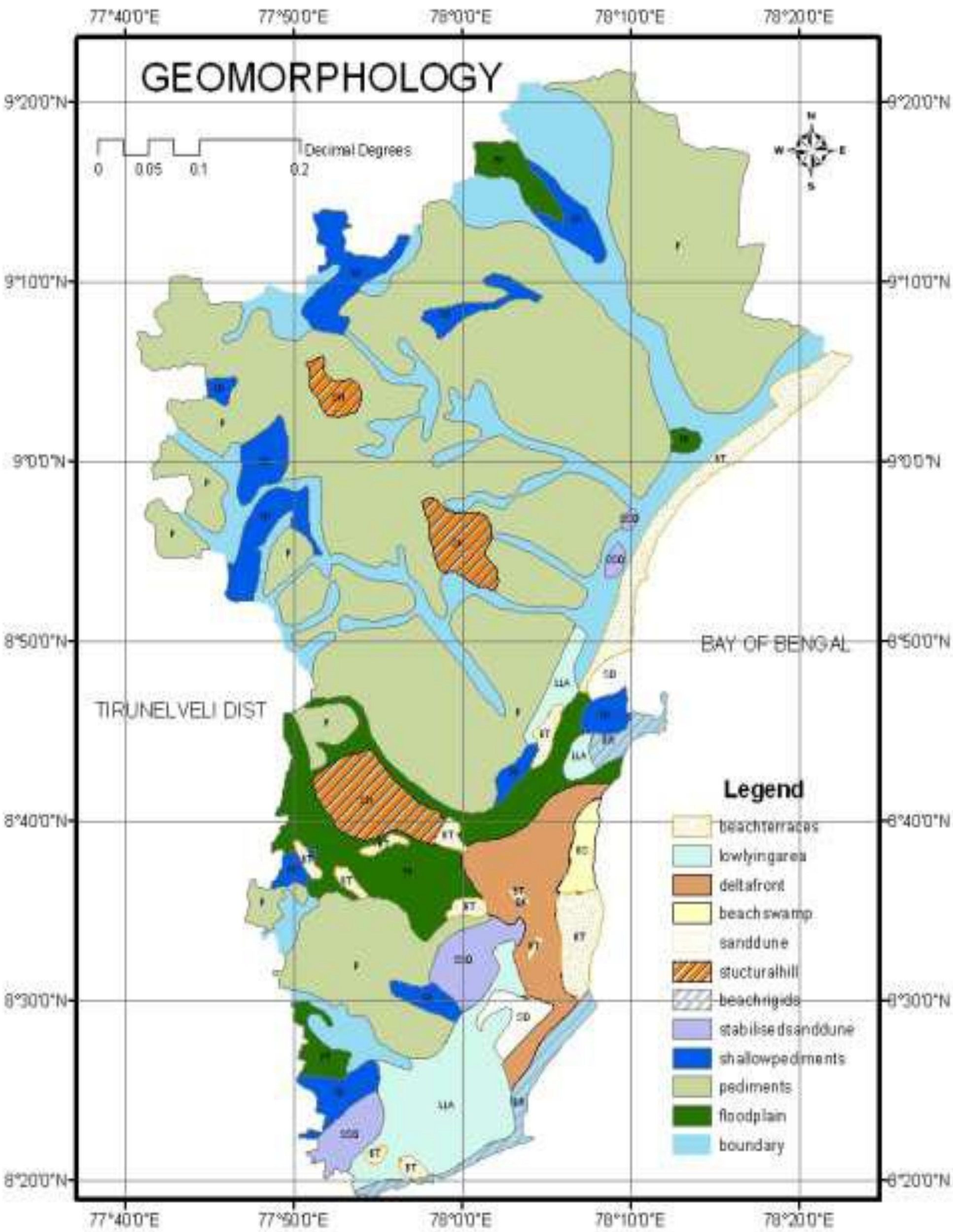

Figure 6: *Geomorphology Map*

D. Landuse and Land Cover Map

The Land use and Land cover Map of Tuticorin district is shown in figure 7. This map clearly classified as forest, settlements, wetlands, water bodies, sandy area, rivers etc.

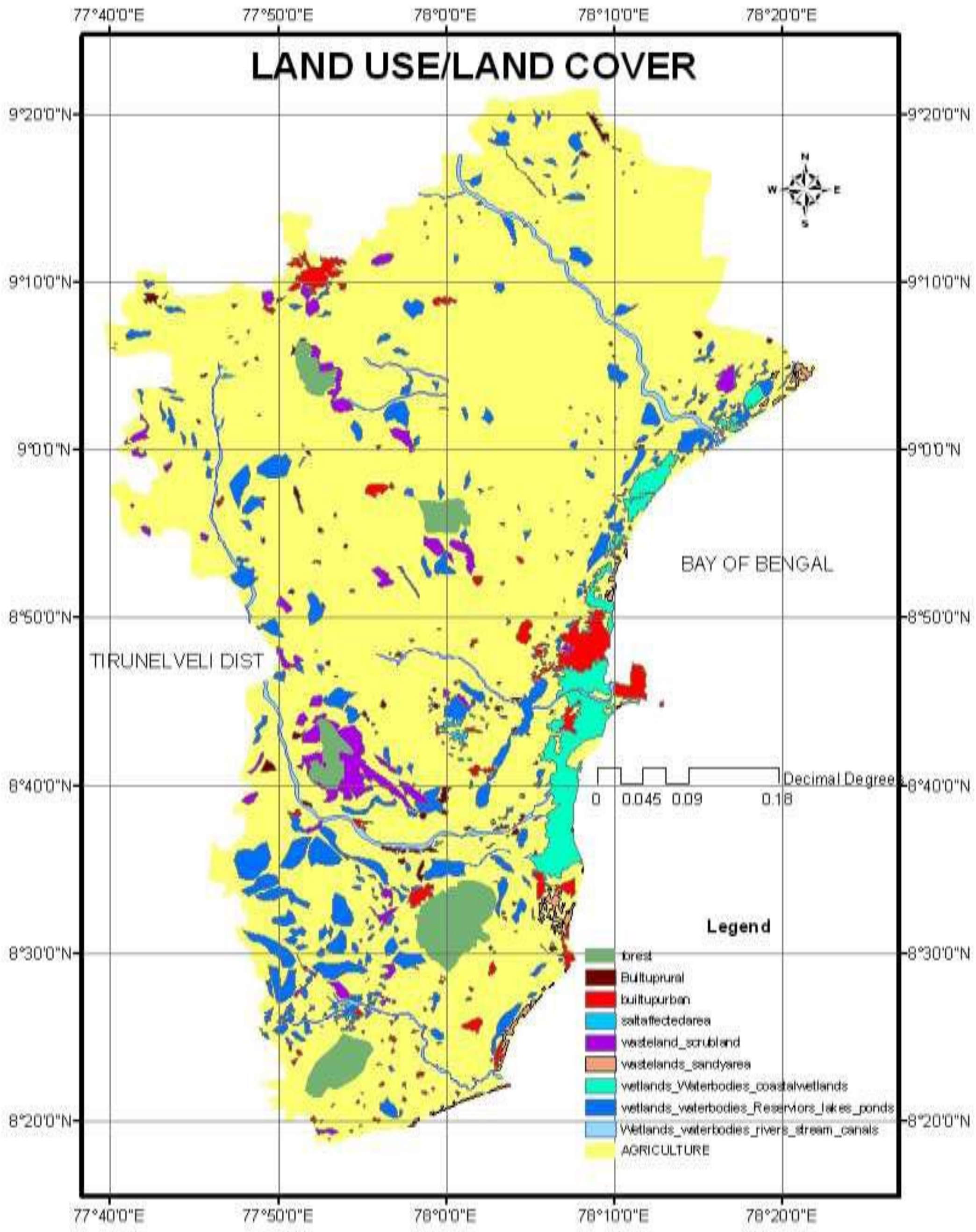

Figure 7: *Land Use and Land Cover Map*

E. Geology Map

The Geology Map of Tuticorin district is shown in figure 8. This map clearly classified as Recent, Kankar, Quartzite, Teri sand, Bio geniesis and Silimate geniesis.

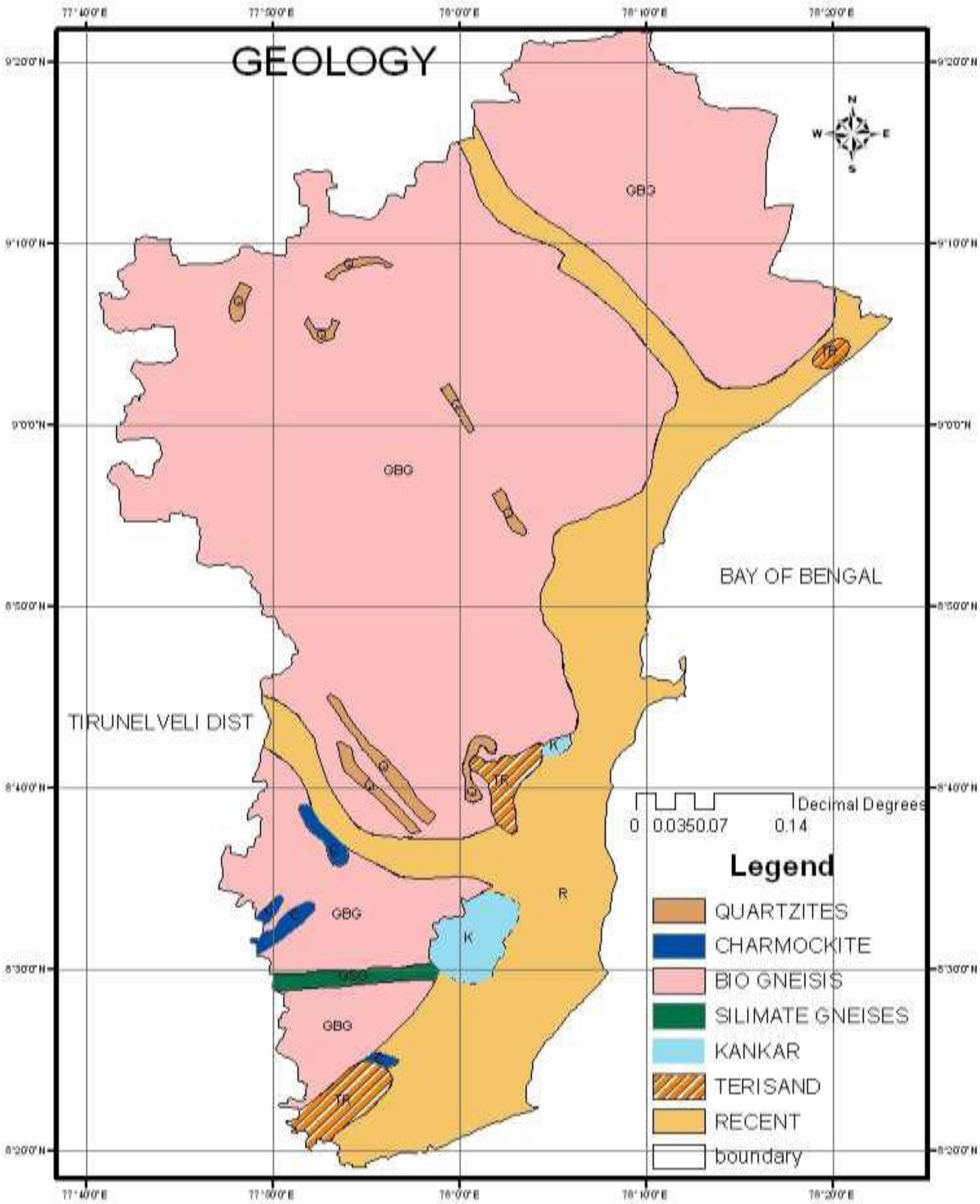

Figure 8: *Geology Map*

F. Soil Map

The Soil Map of Tuticorin district is shown in figure 9. This map was clearly classified as Black soil, Red soil, Teri soil, Newly soil, Sandy soil and Young soil.

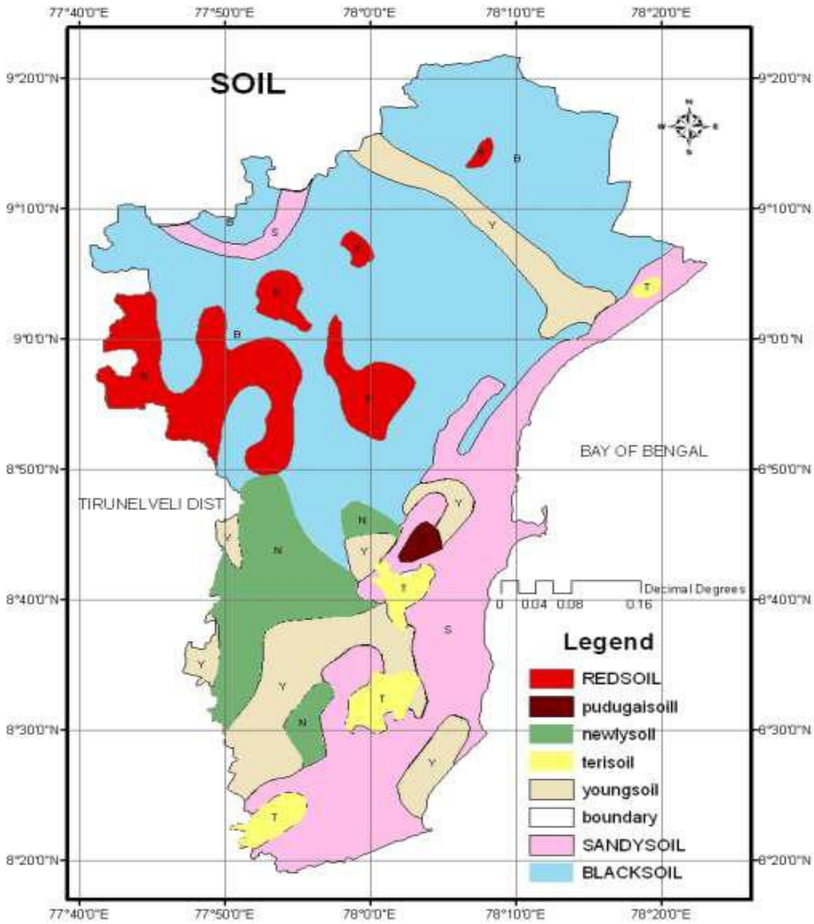

Figure 9: *Soil Map*

5. Conclusion

The coastal processes in Tuticorin coastal area, the shoreline change, land use and land cover, geology, soil and coastal geomorphology were analysed using Remote Sensing and GIS tools. The changes observed at Tuticorin using temporal satellite imageries show that the shoreline dynamics is natural and this is not due to human interference. Coastal processes play a major role in decisive the coastal configuration of this area. The integrative approach using Remote Sensing and GIS tools clearly illustrates both the cause and reasons for the shoreline change. The results of this study will be more useful for shoreline management.

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Research Article **Open Access**

Possibility Studies and Parameter Finding for Interlinking of Thamirabarani and Vaigai Rivers in Tamil Nadu, India

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Abstract Water availability is becoming dearer and dearer day by day in Tamil Nadu due to monsoon vagaries and increasing population propulsion. The spatial and temporal variations in the rainfall over Tamil Nadu has led to denotation of water 'surplus' and water scarce river basins in the state. This project is an attempt for possibility studies and finding parameters for interlinking the rivers in Tamil Nadu state aims at transferring water from water 'surplus' to the water scarce basins. This aims the prevailing reductionist concept of 'surplus' flows in some river basins irrespective of its diverse ecological needs and of its diversion to water scarce regions. The project touches on the fact that though the interlinking proposal has been made to reduce the water scarcity in the rain scarce areas of western and southern parts of Tamil Nadu, the choice of this gigantic project as the appropriate mechanism to achieve the goal is questioned. The project is focused on the justifiability of the assumption of an arithmetic expansion in irrigated land as the only possible solution towards maintaining Tamil Nadu food security. Based on the above observations, it identifies the need for a totally transparent techno-economic and environmental feasibility study and comparison with other possible options, before the interlinking project is given final approval. Using Remote Sensing and Geographic Information System the various parameters such as Soil, Geology, Geomorphology, Land use, Slope, Rainfall, Drainage, Basin, Relief were analyzed. All relevant data the transfer of equitable water could be distributed there by the water scarcity for drinking and irrigation purposes could resolve by linking various water channels.
Keywords *Parallelepiped, Minimum Distance, Mahalanobis Distance, Maximum Likelihood, Spectral Angle Mapper, Spectral Information Divergence, Binary Encoding, Neural Net, ISO data and K-means*

1. Introduction

Water is one of the most significant natural resources. It is a godsend that water constitutes more than three fourths of the area of the earth and hence, it is selected, properly, as 'watery planet' or 'blue planet' [1]. Overall water resources of the earth, the un-utilizable division for more than 99%. In fact, reasonably, a trivial amount of less than 0.4%, including 0.3% of utilizable groundwater and even less proportion surface waters, is available for direct consumption [2-3]. Thus, the serviceable surface waters comprise a very scanty proportion in the entire global water resources. Appropriate planning is essential for sensible exploitation of this precious commodity for striking an appropriate balance between demand and availability, and availability and utilization at the worldwide, provincial and local levels for the sustainability of their ecosystems [8].

1.2. Study Area

Thamirabarani River is 130 kilometers in length and the Thamirabarani basin is situated between latitudes 8.21ºN and 9.13ºN and between 77.10ºE longitudes. The forty meters deep Vanatheertham waterfalls are located near the origin of the Thamirabarani River. The river is feed by its tributaries as well as by monsoons. The Thamirabarani has several tributaries, which join at different points during its course. The tributaries Peyar, Ullar, Karamaniar and Pamba join near the Papanasam Reservoir. A major tributary of Thamirabarani is the Servalar River, which joins at a distance of 22 kilometers from its origin. The Manimuthar River, which originates in the Agathimalai Ranges and joins Thamirabarani near Ambasamudram. Gadana River joins at a distance of 43 kilometres from its origin. The Pachaiyar River joins near Gopalasamudram. Chittar River flows for seventy-three kilometers before joining this River. The river flows for 125 kilometers out of which 75 kilometers are in the Tirunelveli district. The Vaigai is a river in Madurai, Tamil Nadu state of southern India. The major tributaries of the river Vaigai are, Suruliyaru, Mullaiyaaru, Varaganadi, Manajalaru and Kridhumaal. Vaippar is a river in the state of Tamil Nadu. It originates from the hills bordering the state of Kerala and runs through Teni and Virudhunagar districts before entering the Gulf of Mannar. Gunnar is a river flowing in the Virudhunagar and Tirunelveli districts of the state of Tamil Nadu. The sanctuary area is within the 15 m (49 ft.) high embankments of the community irrigation tank. The total length of the embankment is 4.010 km.

2. Methodology

The Methodology provides the framework for the interlinking of two rivers with the aid of Remote Sensing and GIS that has been followed in this project shown in figure 1. The several tributaries should consider while planning about the interlinking of rivers, the main factor should analyzed in this area are shortest way, Land use and Land cover structures, Relief and Distance, Flow and Current of water, Dams, Canals and Slopes. The planning and development is important stage in this project before enter in to the action the various parameters related to environment and social factor should investigate [2]. The various parameter scrutinized in this project are Land use, Land cover, Relief, Drainage, Geology, Geomorphology, Rainfall and River Basins. The four possibility should consider while study about interlinking of rivers they are Dam to River, Canals to Pond, Canal to River, River to River. The multi-layer analysis introduced in this project for analysis several parameter data in the GIS environment, possible area should estimate from the level of classification [9]. The several calculation also considered in this analysis for better finding of possibilities, they are Rainfall estimation, Slope of the Basin, Relief of the Basin, Distance and length of the river and tributaries [9-13].

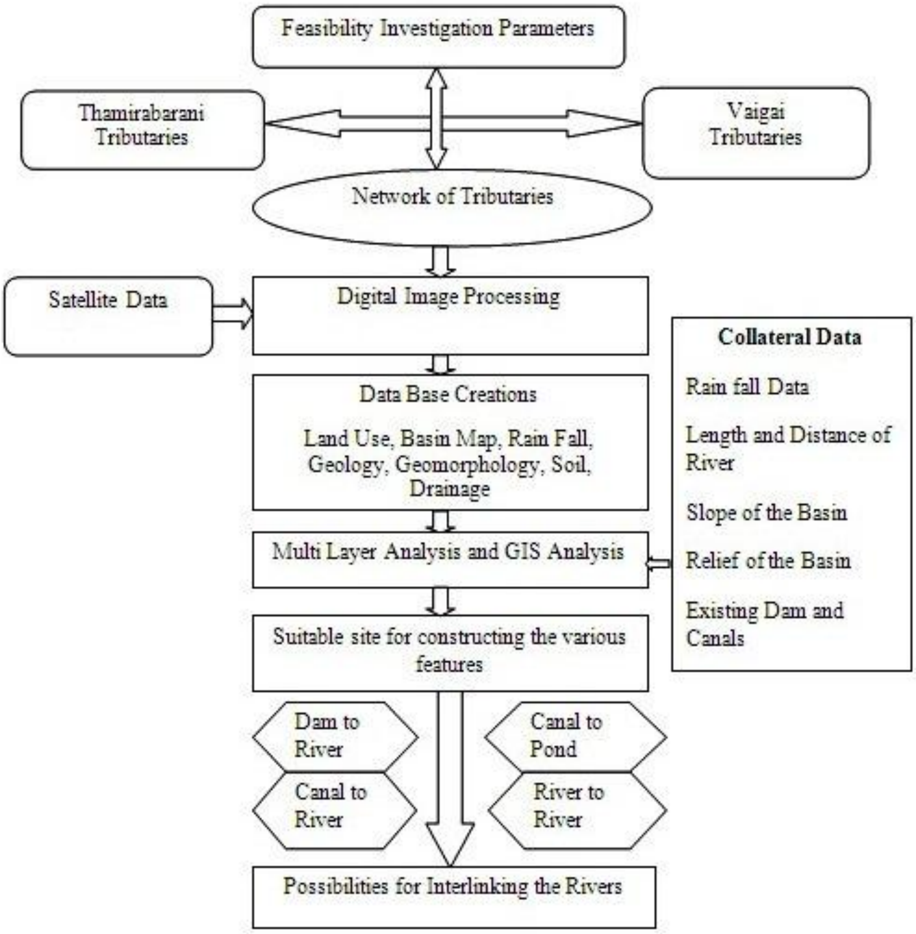

Figure 1: *Frame Work for the Interlinking of two Rivers*

2.1. Thamirabarani River Basin and Sub Basin

The Thamirabarani River consists of 5 River basins and 45 Sub basins [5]. The table 1 shows the detailed element of Thamirabarani River basin and sub basins.

Table 1: *Thamirabarani River Basin and Sub Basin*

S.NO	NAME OF RIVER BASIN	AREA IN HECTARES	NO.	NAME OF THE SUB BASINS	AREA IN HECTARES
1.	Vaippar Basin	72881.98	1	Vasudevavallur I	25971.73
			2	SankaranKoil II	7476.14
			3	SankaranKoil III	6218.72
			4	Thiruvenkadam part	29810.02
			5	Jamin Devarkulam	3405.37
2.	Chithar Minor Basin	235593.8	1.	Vasudevavallur II	28314.15
			2.	Karuppanathi	31777.79
			3.	Naduvakurichi I	2393.20
			4.	Naduvakurichi II	4064.11

			5.	Marukalankulam	5252.10
			6.	Uthumalai	2462.16
			7.	Melaneelithanallur I	5576.53
			8.	Melaneelithanallur II	11063.25
			9.	Senkottai	18734.39
			10.	Tenkasi	21022.38
			11.	Hanumanathi	7596.73
			12.	Chithar I	6020.70
			13.	Chithar II	19486.02
			14.	Kelapavoor	11358.34
			15.	Alankulam	10681.06
			16.	Manur I	23608.29
			17.	Mela-ilanthakulam	1215.90
			18.	Kodikurichi	316.99
			19.	Thiruvenkadam part	10970.58
			20.	Sankarankovil I	5097.28
			21.	Sankarankovil II	8581.85
3.	Thambaraparani Minor Basin	241865.75	1.	Manur II	24655.42
			2.	Ambasamudram	73474.69
			3.	Cheranmadevi	20625.23
			4.	Devanallur	36567.88
			5.	Palayamkottai	26711.53
			6.	Thambaraparani	23650.09
			7.	Kadayam	19987.89
			8.	Pappakudi	16193.01
4.	Nambiar Minor Basin	87258.61	1.	Thirukurinkudi	10489.86
			2.	Therkku Nanguneri	15830.74
			3.	Valliyur	7051.45
			4.	Perunkudi	19644.20
			5.	Nambiar IV	11959.08
			6.	Nambiar V	12666.63
			7.	Radhapuram	9616.65
5.	Karamaniar Minor Basin	44707.87	1.	Karamaniar I	8003.47
			2.	Karamaniar II	10548.77

		3.	Karamaniar III	11569.73
		4.	Thisaiyanvilai	14585.90
Total Area	**682308.00**			**682308.00**

2.2. Vaigai River Basin and Sub Basin

The Vaigai River consists of 4 River basins and 12 Sub basins. The table 2 shows the detailed element of Vaigai river basin and sub basins.

Table 2: *Vaigai River Basin and Sub Basin*

S.NO	NAME OF RIVER BASIN	AREA IN HECTARES	NO.	NAME OF THE SUB BASINS	AREA IN HECTARES
1.	Vaigai	4,64,051	1.	Suruliyar	1,15,496
			2.	Thalaivaigai	45,894
			3.	Periyakulam	36,830
			4.	Andipatti	21,958
			5.	Cholavandhan	1,68,000
			6.	Uppar	37,021
			7.	Manjalar	38,852
2.	Gunnar	1,56,044	1.	Therkar	62,668
			2.	Goundanadhi	93,376
3.	Vaippar	27,712	1.	Arjunanadhi	23,969
4.	Pambar	28,878	1.	Thirumanimuthar	23,969
			2.	Upper Palar	4,909
	Total Area	**6,76,685**			**6,76,685**

2.3. Rainfall Data

The rainfall various according the season of the area. These majorly classified in four seasons such winter, hot weather period, southwest monsoon and north east monsoon [7]. The table 3 and 4 shows the rainfall data for Tirunelveli and Madurai respectively.

Table 3: *Rainfall Data for Tirunelveli District*

SEASONS	PERIOD	RAINFALL in mm	PERCENTAGE
Winter	Jan. & Feb.	79.18	9%
Hot Weather period	Mar. to May	172.39	19.6%
Southwest Monsoon	June. to Sep	147.98	16.8%
Northeast Monsoon	Oct. to Dec.	480.23	54.6%
	Total	**879.78**	**100.00**

Table 4: *Rainfall Data for Madurai District*

SEASONS	PERIOD	RAINFALL in mm	PERCENTAGE
Winter	Jan. & Feb.	52.3	6.1
Hot Weather period	Mar. to May	171.0	19.7
Southwest Monsoon	Jun. to Sep.	242.3	27.9
Northeast Monsoon	Oct. to Dec.	401.9	46.3
	Total	**867.5**	**100.00**

3. Results

3.1. Pictorial Representation of Parameters

The various parameter such Land use, Rainfall, Drainage, Geology, Geomorphology and Soil map of Thamirabarai and Vaigai river is shown in figures 2 to 12 were generate with the help of Remote Sensing and Geographical Information System analysis. The various image processing technique used in this analysis such as parallelepiped, Minimum Distance, Mahalanobis Distance, Maximum Likelihood, Spectral Angle Mapper, Spectral Information Divergence, Binary Encoding, Neural Net, ISO data and K-means with the help of ENVI and ERDAS image processing software [3–6]. These factor should consider for the initial process for interlinking thamirbarani and vaigai rivers, these clearly shows the rain fall data, drainage possibilities and existing, land coverage details, structure and features of earth surface.

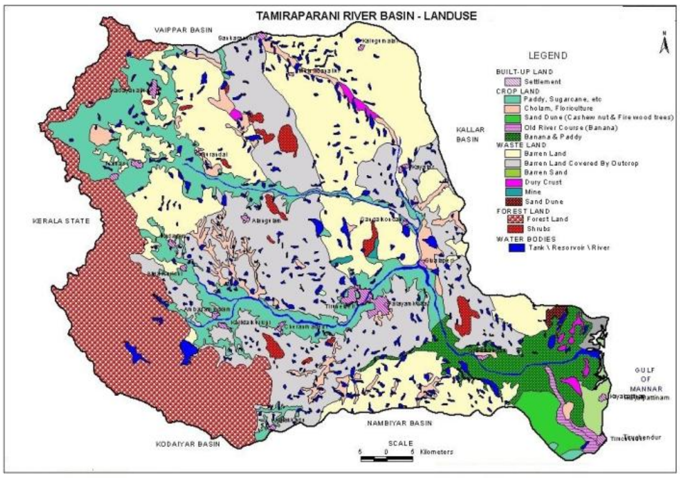

Figure 2: *Thamirabarani Land Use Map*

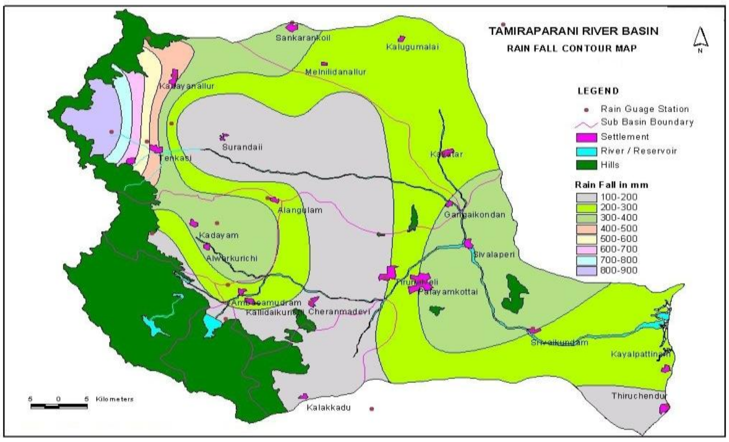

Figure 3: *Thamirabarani Rainfall Map*

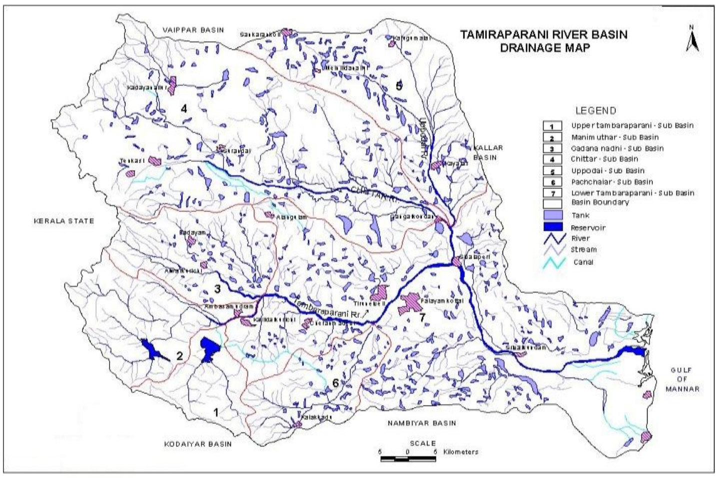

Figure 4: *Thamirabarani Drainage Map*

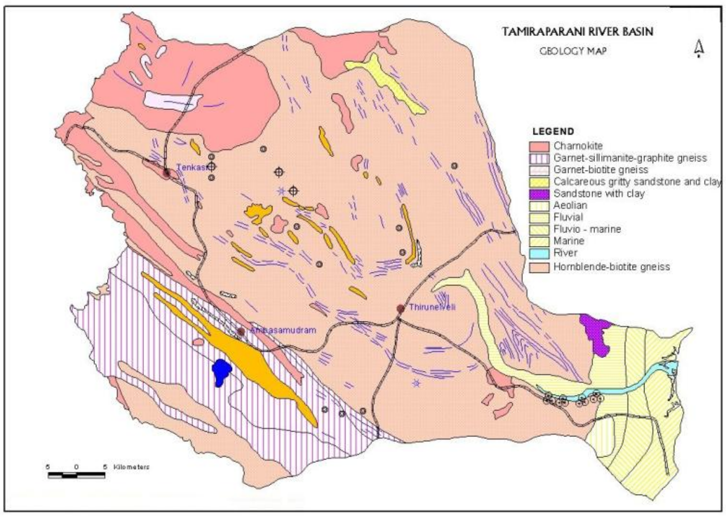

Figure 5: *Thamirabarani Geology Map*

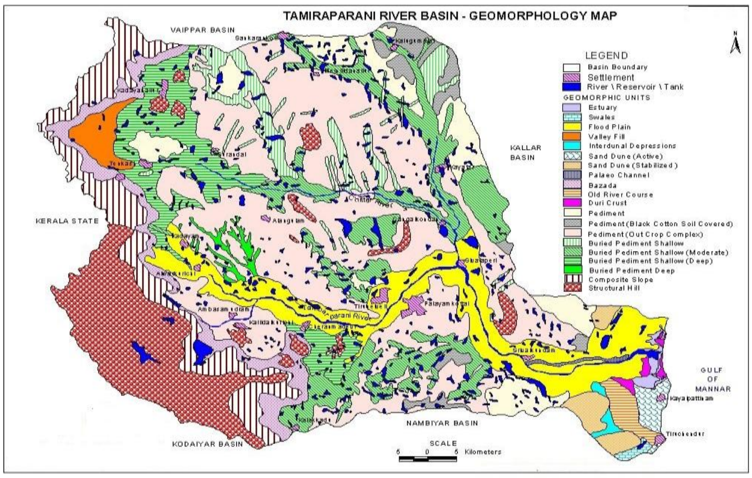

Figure 6: *Thamirabarani Geomorphology Map*

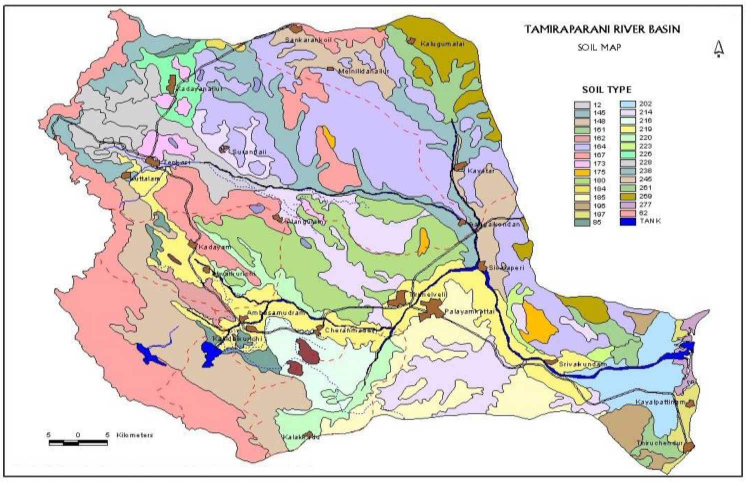

Figure 7: *Thamirabarani Soil Map*

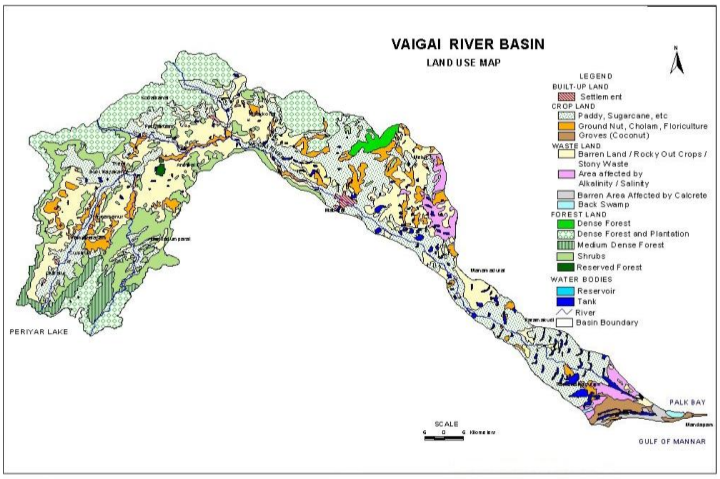

Figure 8: *Vaigai Landuse Map*

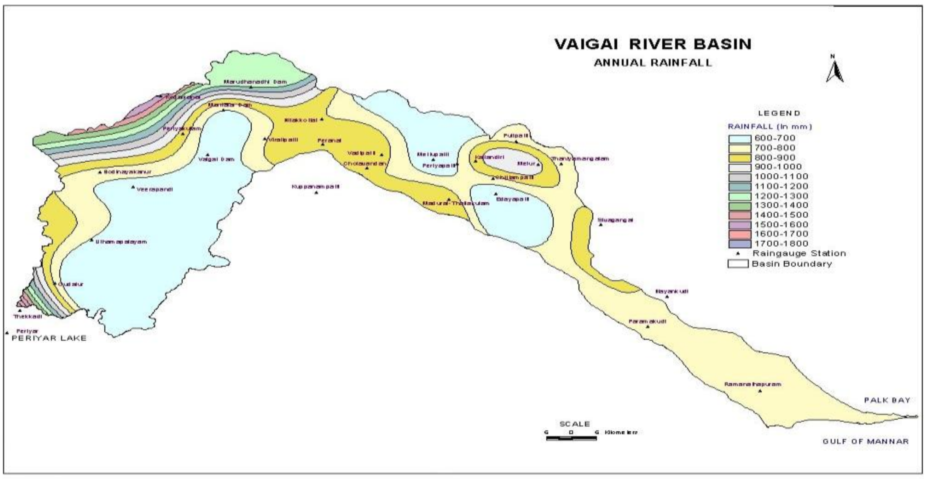

Figure 9: *Vaigai Rainfall Map*

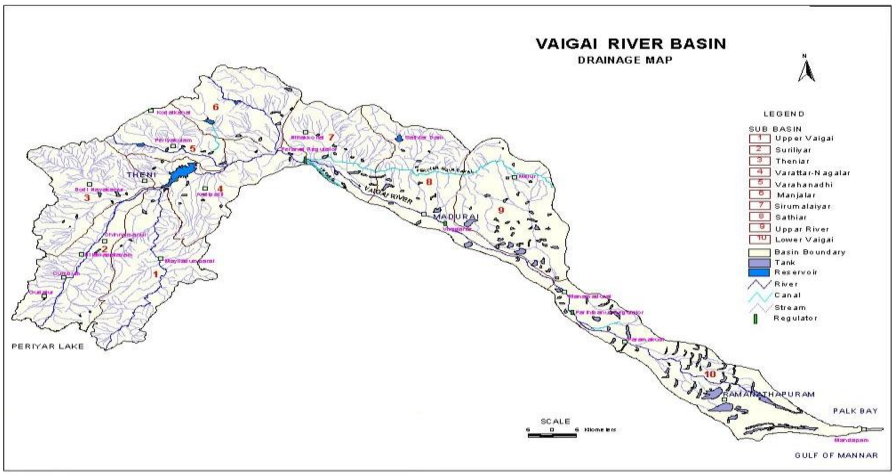

Figure 10: Vaigai *Drainage Map*

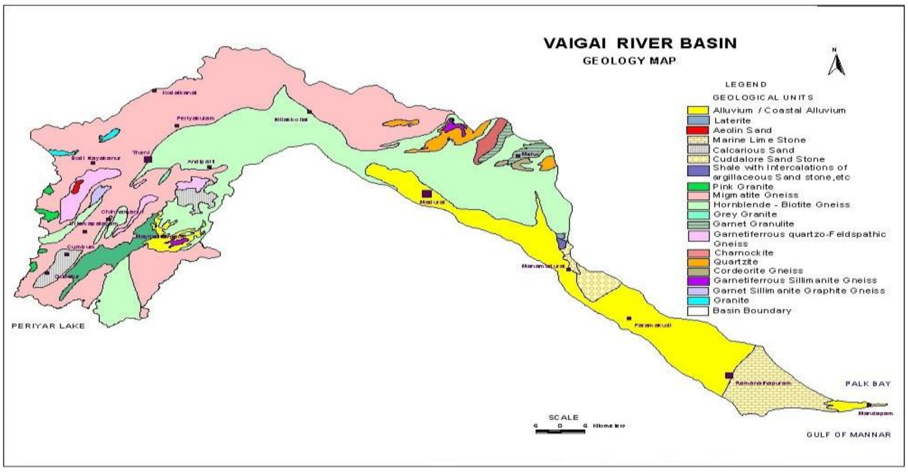

Figure 11: *Vaigai Geology Map*

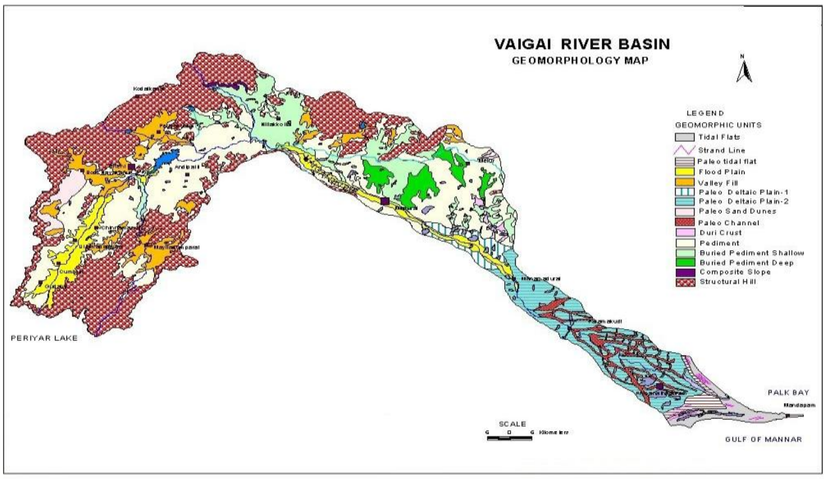

Figure 12: *Vaigai Geomorphology Map*

4. Conclusion

This project provides information at a provincial level about the various possibilities and parameters for interlinking of Thamirabarani River and Vaigai River. The study shows the environmental and social factor are majorly supporting for achieving interlinking of rivers. The Thamirabarani and Vaigai Rivers origin and settling area present inside the Tamilnadu, so there is no possibility of confliction among the states. While interlinking these rivers unquestionably the total south Tamilnadu water scarcity will be reduced, majorly the following districts Dindigul, Theni, Tuticorin, Sivanganga, Madurai, Virdhunagar, Ramanathapuram, Tirunelveli and Kanyakumari will get benefit and possibility of increase the water storage capacity for the irrigation and drinking purpose. In other hand interlinking of thamirabarani and Vaigai Rivers helps to control the floods in south Tamilnadu and the surplus water flow may be used for diverse purpose such as Agriculture, Irrigation, Electric power generation and so on.

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Review Article

Open Access

Integrating of Urban Growth Modelling and Utility Management System using Spatio Temporal Data Mining

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Abstract The proposed research focus on accomplish better Modelling methods and Classification technique to integrate urban growth and utility management with the help of Spatio-Temporal Data Mining. Now a days the urban growth increasing rapidly in other hand providing utility services to the society getting congestion and hassle. This research aid to classify urban growth level using Spatial-Temporal data and better utility service system is attain with the facilitate of Knowledge Based Integration (KBI). The broader concept of urban growth modelling provide the detail of Land cover/ Land use, Changes, Growth or Reduction of feature in area extract with the assist of Multiple Level Classification (MLC). In the province of urban growth modelling can be make use of scrutinize, estimate and forecasting urban systems to support Utility Management and Decision-Making process. In Remote sensing technique, modelling attains from the Spatial and Temporal elements obtain from Topographic Maps, Aerial Photos, Satellite Images, Several Databases and Statistical Information from Private or Government Organization. The proposed "Multiple Level Classification" (MLC) technique consists of Cellular Automata (CA) and Spatial statistics. Thus the hierarchy level of urban growth classification have to integrate among Utility Management with the facilitate of "Knowledge Based Integration" (KBI) includes techniques such as Artificial Neural Network (ANN) and Fuzzy Logic. In this utility covers the basic service such Electricity Transmission elements, Water supply system, Hospital/Emergency unit, Fuel /Gas link, Road Network and Telecommunication Network, etc. This research mainly helps to provide various utility services in efficient way to the developing urban and diminish the time span and cost for utility service.
Keywords *Multiple Level Classification, Artificial Neural Network, Fuzzy logic, Knowledge Based Integration, Cellular Automata, Remote Sensing, Geographic Information System*

1. Introduction

Now a days the urban growth increasing rapidly in other hand providing utility services to the society getting congestion and hassle [1]. The present research is to study exhaustively the integration of Urban Growth Modelling and Utility Management System. It is required to study the various processing and modelling techniques in Remote Sensing and GIS [2-4]. The present research will suggest the system like Multiple Level Classification (MLC) and Knowledge Based Integration (KBI) technique intended for incorporate the Urban Growth Scrutinize and Utility Management System. The present work however may be confined to three steps, they are Determination of urban growth Level and categorize the area with the aid of Cellular Automata (CA) and Spatial Statistic methods, Determination of Utility Management System with the help of Artificial Neural Network (ANN) and Fuzzy Logic and Integration of Urban Growth Modelling and Utility Management System using Knowledge Based Integration (KBI).

2. Review of Literature

Jean (2008) sited that the Cellular Automata (CA) model developed to simulate land-use changes and analyze urban growth level. Historical Land-use Maps are read and factors responsible for driving the Land-use changes, such as the distance to the Road Network, are identified. A frequency histogram is produced for each combination of Land-use changes, neighbourhood configuration, and driving factor. This information is analyzed to automatically create the transition rules that can be applied for the simulation. Jeremy Mennis (2005) narrated that Multiple level association rule mining is supported by the development of a hierarchical classification scheme for each variable. Further research in Spatio-Temporal association rule mining should address issues of data integration, data classification, the representation and calculation of spatial relationships, and strategies for finding 'interesting' rules.

Clarke and Gaydos (1998) described the complexity of urban growth, first they principally touch on spatial and decision-making complexity, with little about temporal complexity. The former includes pattern-oriented growth simulation.Torrens and O'Sullivan (2001) narrated that CA models are constrained by their simplicity, and their ability to represent real-world phenomena is often diluted by their abstract characteristics. Z Shang (1998) says about ANN is composed of many non-linear processing units that are connected to each other and collectively perform a single task. One of the main properties of an ANN utilized in this study is the ability to learn complex relationships between input and output vectors which are very difficult to embody in conventional algorithmic methods. This task is carried out by a process of learning from examples presented to the ANN. During learning, known input-output pairs (e.g. historical data), called the training set, are applied to the ANN. The ANN learns by adjusting or adapting the strengths of the connections between processing units, by comparing the output of the ANN to the expected output. Larsen (1989) described that fuzzy Logic decision tool discussed here provides a mechanism to support systematic decision making in knowledge-based planning systems and decision aids. It has been applied to the process of knowledge acquisition in order to structure and build knowledge bases as well as construct user interfaces that support subjective decision making.

3. Outline of Methodology

The main goal of this research is to provide Urban Growth Modelling and Utility Management in efficient way with the help of Remote Sensing and GIS technique. The Spatio-Temporal Data Mining is the extraction of unknown and implied knowledge, structures, elements, Spatio-Temporal relationships, or patterns stored in Spatio-Temporal databases, it includes Spatio-Temporal forecast and trend analysis, Spatio-Temporal association rule mining, Spatio-Temporal sequential patterns mining, Spatio-Temporal Clustering and Classification [5]. In this research the urban development can be classify from high resolution Spatio-Temporal data. In this proposed research the new approach "Multiple Level Classification" (MLC) has been suggested to attain Level I (Residential, Population Density, and Natural System), Level II and III classification (Urban Land use change on the local/community level, socioeconomic variable) with the help of Cellular Automata (CA) [6–8] and Spatial Statistics techniques [9]. The Cellular Automata (CA) is highly effectual tool to study the dynamic of urban growth for the reason that it effectively encoding various spatial structures and managing Spatio-Temporal dimensions [5,6] [4]. Here spatial statistics mainly help us to find the Topological and Geometric properties of an area. Thus the hierarchy level of classification helps to integrate the Utility Management for identify the basic service need for extend urban area. In this utility Management the various services are extracted from Spatial Temporal and non-Spatial temporal data [10,11]. Thus the "Knowledge Based Integration (KBI) assist to integrate the entire utility in single package for providing the service to the newly grow urban without any barrier with the aid of Data Base Management System (DBMS), Artificial Neural Network (ANN) and Fuzzy Logic techniques. The utility management system suggesting rank for selecting right and efficient way to provide service for the urban area.

4. Conclusion

This project mainly facilitate for Urban Planning and Development, the provisional level of this study majorly lend a hand to society for providing utilities without any barrier. The new approach Knowledge Based Integration helps to integrate urban growth modelling and Utility management System. In this proposed project majorly covers the basic utility service such Electricity Transmission elements, Water supply system, Hospital/Emergency unit, Fuel/Gas link , Road Network and Telecommunication Network, etc. The prominent growth of urban may analyse over a period and providing utility to the society is difficult and time consuming but in this planned level of study focusing on keen interest on computing the urban growth and utility management simultaneously. The various new conceptual used in this project overcome all barriers which all faced in conventional planning and management and its helps to study about developed urban and also newly grown urban. The work show that the available Remote Sensing satellite data and Geographical Information System in collaboration with various field survey data can be best utilized for planning and development of an urban area.

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Research Article **Open Access**

Groundwater Geochemistry of Neyveli Lignite Mine-Industrial Complex, Tamil Nadu, India and Its Suitability for Irrigation

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Abstract This study was undertaken to assess the quality of groundwater for irrigation and level of trace metal concentration in the surface and groundwater bodies from Neyveli lignite mine-industrial complex which is located in Cuddalore district, Tamil Nadu, India. The hydrogeology of the Neyveli groundwater basin is extremely complex, consisting of a series of productive, confined aquifers below the lignite seam in both Mine I and II areas, while a semi-confined aquifer lies above the seam and occurs only in the Mine II area. The suitability of groundwater quality for agricultural purposes in and around Neyveli lignite mine-industrial complex was assessed by measuring physicochemical parameters, including major cation and anion compositions, pH, total dissolved solids, electrical conductivity, and trace metals. The results of the chemical analysis of the groundwater showed that concentrations of ions vary widely and the most prevalent water type is mixed $CaNaHCO_3$, followed by other water types: mixed CaMgCl types and NaCl which is in relation with their interactions with the geological formations of the basin, dissolution of feldspars and chloride and bicarbonate minerals, and anthropogenic activities. The most dominant class is C1-S1, C2-S1 (85% PRM and 74% POM) in the study area, indicating that sodicity is very low and salinity is medium, and that these waters are suitable for irrigation in almost all soils. Based on sodium absorption ratio the groundwater of the study area is suitable for all types of crops and soil except for those crops sensitive to Na and based RSC values of the groundwater, considered safe. Based on the parameters such as TDS, EC, SO_4, Cl and Wilcox diagram about 99% of samples are suitable for irrigation. The average concentration of trace metals (Fe, Mn, Cr, Zn, Pb, and Cu) in groundwater samples fall within the permissible limit, with the exception of Ni which is recorded higher than the permissible limit which may retard growth and metabolic activities while the groundwater used for irrigation.

Keywords *Hydrogeochemistry, Irrigation Suitability, Industrial Area, Lignite Mine, Neyveli, Trace Metals*

1. Introduction

Quality of water is the function of its physical, chemical, biological and geological parameters [1], which depend upon the soluble products of weathering and decomposition and the related changes that occur with respect to time and space [2-4]. All groundwater contains minerals carried in solution, the type and concentration of which depend upon the surface and subsurface environment, rate of groundwater movement and source of groundwater [5-7]. Man can also adversely alter the chemical quality of groundwater by permitting highly mineralized water to enter into fresh water through mining activity, industrial activity and by disposal of solid and liquid wastes which affects the groundwater through leaching. Pollution of groundwater due to external contaminants such as industrial, urban and agricultural activities is quite well documented [3-4, 8-13]. One of the aspects on which enough attention has not been focused is the degradation of groundwater quality caused by opencast mining activity, in that the interaction between rock, soil and water has led to increasing content of various cations, anions and trace metals in groundwater. Groundwater is of great importance for agriculture in the province of Neyveli, there is a necessary research requirement to provide improved understanding of the quality of groundwater in this region. Many studies have been undertaken in the last two decades and successfully assessed the groundwater quality for irrigation [14-21] which have been useful for agricultural management plan. Therefore, the objectives of the present study are to characterize the main hydrogeochemical features of the groundwater from Neyveli Mine-industrial complex area and its surroundings and to assess the suitability of groundwater for Irrigation purposes.

2. Study Area

The Neyveli Mine-industrial complex is located in Cuddalore district, Tamil Nadu, India (Figure 1). The area has a tropical climate with the highest and lowest temperatures recorded in June (40.3°C) and January (20.4°C), respectively. At the mine site, the average annual precipitation is 1369 mm with 55% and 45% rainfall from the NE and SW monsoons, respectively. The area gently slopes towards southeast and east, and is not drained by any major river except for a small ephemeral stream (the Paravannar River) flowing east. This carries mine water and industrial effluents instead of natural water, and discharges into the Walaza and Perumal Ponds east of the lignite mines. The study area is underlain by the Tertiary Cuddalore Formation and by recent alluvium. The Cuddalore sandstones cover mostly the northern and western parts, while the alluvium covers mostly the eastern and south-eastern parts of the study area. The lignite occurs in the Cuddalore Formation at depths ranging from 45 to 120 m below ground level (bgl).

The hydrogeology of the Neyveli Groundwater basin is extremely complex, consisting of a series of productive, confined aquifers below the lignite seam in both Mine I and II areas, while a semi-confined aquifer lies above the seam and occurs only in the Mine II area. In the Cuddalore sandstones, groundwater occurs in unconfined, semi-confined, and confined conditions; in the alluvium, it occurs in unconfined condition. In the study area, both Tertiary Cuddalore Formation and the recent alluvium form a potential aquifer system.

Around the mine, the ground is either flat or undulating with elevations ranging from 100 to 337 ft. above mean sea level with a general slope to the south and southeast. Of the mean annual rainfall of about 1080 mm, maximum rainfall is recorded between October and December during the northeast monsoon. The Gadilam and Vellar Rivers and their tributaries constitute the principal drainage. These rivers are ephemeral. The study area includes two very large (Mines I and II) and one small (Mine IA) opencast lignite mines, associated industries (two pit-head thermal power plants, a urea plant, and a briquetting and carbonization plant) that are operated by Neyveli Lignite Corporation Ltd. (NLC), and an independent power plant.

Generally, about 550,000 L/min of water are pumped from the pits in a normal season, though much more is pumped during monsoons. Huge quantities of untreated wastewater are also discharged from fly-ash ponds and associated industries into natural reservoirs (Peria, Kolakudi, Walaza and Perumal Ponds, and Paravannar River) and agricultural fields. The water in the ponds and river is severely contaminated with heavy metals, but has been used for the last several decades by nearby villages for irrigation, animal watering, bathing, and washing, etc. Today, about 8,100 ha of agricultural land are irrigated by wastewater discharged from the mine pits and associated industries.

3. Materials and Methods

Seventy seven representative ground water samples were collected in and Neyevli mine industrial complex and two surface water samples from the vicinity of the mine-industry area for trace metal analysis. Sampling was carried out in pre and post-monsoon seasons during 2006. Water samples were collected in sterile 1 L polyethylene bottles and after being filtered (pore size-0.45 μm); each sample was treated with 10 ml HNO_3 to prevent possible precipitation of heavy metals. The water samples were analyzed for water quality (Na, K, Ca, Mg, CO_3, HCO_3, Cl, PO_4, NO_2, and NO_3) and heavy metals according to international standard methods [22]. The analyses of Fe, Mn, Cr, Cu, Ni, Pb, and Zn were performed in the Department of Applied Geology, University of Madras, India using Atomic Absorption Spectrophotometer – Graphite Furnace (Perkin Elmer AAanalyst700).

4. Results and Discussion

4.1. Water Chemistry and Its Spatial Distribution

The Summary of statistical data of groundwater from Neyveli lignite mine-industrial complex is listed in Table 1. The pH of the groundwater during premonsoon (PRM) ranges from 5.7 to 8.5, with an average of 6.9 (Figure 2a), indicating the overall neutral nature of the samples. During postmonsoon (POM), the pH is ranged between 5.9 and 7.9, with a mean of 6.7 (Figure 2b). The highest value is recorded at station 37 (near Periakurichi) and station 3 (Utangalmangalam), western part in PRM and POM seasons respectively. The TDS during PRM is ranged from 19 to 986 mg/l, with an average value of 283 mg/l and during POM; it is ranged between 21 and 1,864 mg/l., (avg. 319 mg/l). The EC of the groundwater during PRM ranged from 30 to 1540 mg/l, with an average value of 441 mg/l. During POM, the EC ranged from 33 to 2,913 mg/l, with an average of 498 mg/l. The highest value of was recorded near the Andikuppam outlet in the eastern part, at Station 12, while the lowest value was recorded near Thekkruppu 9 (Station 24) and Kellakiruppu (Station 24) in the eastern part of the study area during PRM and POM seasons respectively (Figure 2 c, d).

Sodium is the most dominant cation, and the order of abundance of cations is $Na^{+}> Ca^{2+}> Mg^{2+}> K^{+}$. The seasonal effect does not have any impact on the order of abundance, but it does change the concentration of various ions present in the groundwater. The sodium concentration in the groundwater of the study area is ranged from 2.8 to 408 mg/l (PRM); 3.3 to 297.3 mg/l (POM), with an average value of 55.8 and 43.4 mg/l during PRM and POM seasons respectively. The highest value is recorded near the Gangaikondan outlet in the eastern part of the study area at Station 12, during both seasons while lowest value was recorded in Seduthankuppam (Station 21), and near Marugur in the western part (Station 28) during PRM and POM seasons respectively (Figure 3 a, b). Potassium concentration is recorded nil to 92.9 mg/l, (avg. 7.5 mg/l) and nil to 69.6 mg/l, (5.6 mg/l) in PRM and POM seasons respectively. The highest value is recorded near the Thandavakuppam outlet in the western part of Neyveli, (Station 19), while the lower values were recorded in the eastern part of the study area for both seasons (Figure 3 c, d). Calcium is the second dominating ion in the groundwater of the study area is ranged between 1.1 and 355 mg/l (avg.30.8), in PRM and 0.8 and 333.1 mg/l (avg.25.6), in POM respectively. The highest value is recorded near the Gangaikondan outlet (Station 12) in the eastern part of the study area, while lowest values is recorded Deviakuppam (Station 23) and near Vadakumelur (Station 2) during PRM and POM seasons respectively (Figure 3 e, f). The Mg concentration is observed as 0.6 to 61.5 mg/l, with an average value of 21.5 during PRM and 0.3 to 51.5 mg/l, (avg. 17.8 mg/l) during POM. The highest value is recorded near the Melpathi outlet in the western part of Neyveli, (Station 53), while the lowest value was recorded at near Thekkruppu (Station 27) and near Nandukuzhi (station 23) in the eastern part of the study area in PRM and POM seasons respectively (Figure 3 g, h).

During PRM, the carbonate content is recorded as nil to 30.8 mg/l (avg. 6.2 mg/l) and 0.9 to 22.5 mg/l, (avg. 4.8 mg/l) during POM. The highest value is recorded near the Vadakumelur outlet (Station 2) eastern part of the study area, and lowest values are recorded in the western part of the study area during PRM. During POM, the highest and lowest values during PRM and POM seasons are recorded near the Periakovialkuppam outlet (Station 9) in the eastern part and near Kunnakurichi (Station 2) in the western part of the study area (Figure 4 a, b). The bicarbonate content is higher in PRM as 10 to 270 mg/l, with an average of 81.7 mg/l compared to POM (4.9 to 258.1 mg/l, avg. 63.8mg/l). The highest value is recorded near the Kolagudi outlet (Station 33) in the western part of the study area, for both seasons, while the least value is recorded at Thekkruppu (Station 27) and Kellakiruppu (Station 24) in the eastern part of the study area during PRM and POM respectively (Figure 4 c, d). The sulfate concentration ranged between 1.5 and 362.6 mg/l, (avg.94.3 mg/l) during PRM while in POM, ranged from 2.4 to 330 mg/l, with an average of 78.3 mg/l. The highest value is recorded near the Vadukkuvellur outlet (Station 11) in the western part of the study area for both seasons, while the least value was recorded in the western parts near Marugur at Station 28 and near Vallam (Station 25) during PRM and POM seasons respectively (Figure 4 e, f). Chloride is the dominant anion, ranged from 8.00 to 757.2 mg/l, (avg. 79.4 mg/l) in PRM and 3.2 to 637.4 mg/l, (avg. 63.4.mg/l) in POM seasons respectively. The highest value is recorded near the Andikuppam outlet (Station 12), in the eastern part of the study area during both seasons, and the lowest value is recorded in the western part of the study area near Vallam (Station 25) during PRM and near Kellakiruppu (Station 24) in the eastern part of the study area during POM season (Figure 4 g, h).

During PRM, the phosphate content is recorded as 0.02 to 5.04 mg/l, with an average value of 0.49 mg/l and during POM; it is ranged between 0.02 and 1.2 mg/l, with an average of 0.22 mg/l. The nitrite concentrations vary between nil and 1.51 mg/l in PRM with an average of 0.07 mg/l while during POM nitrite content is observed lower (nil to 1, avg. 0.07 mg/l). The nitrate concentration in PRM is ranged from 0.2 to 89.3 mg/l, with an average of 12.8 and in POM; it is ranged from 0.07 to 68.3 mg/l, with an average of 8.1 mg/l. The relatively higher concentrations of nitrate values in many of the stations in the study area reveal that there exist intensive agricultural activities, and the fertilizers would have contributed to the nitrate values. In both seasons, there is no much change in the spatial distribution pattern of nitrate and it is almost isotropic.

Table 1: *Summary of statistical data of groundwater from Neyveli lignite mine-industrial complex, Tamil Nadu, India*

Parameters (mg/l)	PRM					POM					R
	Min	Max	Mean	σ	Var	Min	Max	Mean	σ	Var	
pH	5.7	8.5	6.9	0.6	7	5.9	7.9	6.7	0.6	7	S
EC(mS/cm)	30	1540	441	577.0	333987	33	2913	498.0	498.0	248333	N
TDS	19.0	986.0	283.0	370.0	136801	21.0	1864.0	319.0	370.0	136932	N
Ca^{2+}	1.1	355.0	30.8	48.9	2386	0.8	333.1	25.6	44.4	1973	N
Mg^{2+}	1.0	61.5	21.5	12.4	153	0.3	51.5	17.8	15.2	230	S
Na^{+}	2.8	408.0	55.8	64.5	4156	2.3	449.5	43.4	61.0	3720	N
K+	0.0	92.9	7.5	14.6	214	0.0	69.6	5.6	10.0	100	N
CO_3^{-2}	0.0	30.8	6.2	5.3	28	0.9	22.5	4.8	3.9	5	N
HCO3-	10.0	270.0	81.7	67.1	4503	4.9	258.1	63.8	60.5	3657	N
SO_4^{2-}	1.5	362.4	94.3	109.7	12032	2.4	330.0	78.3	95.6	9130	N
Cl-	8.0	757.2	79.4	100.9	10181	3.2	637.4	63.4	86.5	7480	N
NO^{3-}	0.2	89.3	12.8	18.6	347	0.1	68.3	8.1	13.5	182	N
NO^{2-}	0.0	1.5	0.1	0.2	0	0.0	1.0	0.1	0.1	0	N
PO_4^{3-}	0.0	5.0	0.5	0.8	1	0.0	1.2	0.2	0.2	0	S

s- standard deviation Var-variance S-significant, N-non-significant, R- Result

4.2. Hydrochemical Facies

The evolution of hydrochemical parameters of groundwater can be understood by plotting the concentration of major cations and anions in the Piper diagram [23]. Figure 5a shows that most of the groundwater samples analyzed during the PRM fall in the field of mixed $CaNaHCO_3$, mixed CaMgCl and NaCl. Some of the values also fall in the field of $CaHCO_3$ and CaCl type. During POM (Figure 5b), most of the values fall in the field of mixed $CaNaHCO_3$, mixed CaMgCl, NaCl and CaCl types. Similar to PRM, some of the values fall in the field of $CaHCO_3$ and $NaHCO_3$. Water types NaCl and mixed CaMgCl suggest the mixing of high salinity water caused from surface contamination sources followed by ion exchange reactions. Some of the samples show higher content of Na coupled with low Ca content, suggesting that Ca^{2+}-Na^{+} ion exchange is an important geochemical process for the NaCl type of groundwater. From the plot, it is observed that alkalis (Na^{+} and K^{+}) exceed the alkaline earths (Ca^{2+} and Mg^{2+}), and Cl^{-} exceeds the other anions. This type of water generally creates salinity problems for the irrigation use.

4.3. Chemical Characteristics of Major Ions

The plot of equilines (Figures 6a - 6l) for both the seasons shows a marked difference. In PRM, the plot of Na+K vs. Cl (Figure 6a) shows that most of the values fall just above and below the equiline, except a few values, which suggests that most of the alkali ions are balanced by the chloride ions. Also, in the plot of Ca+Mg vs. HCO_3+SO_4, (Figure 6b) the distribution pattern of the points follows almost that of alkali vs. Cl type (Figure 6e), but with fewer points deviating from the 1:1 equiline, reflecting that HCO_3+SO_4 anions balance the alkaline earth metals in these groundwater samples (Figure 6f). During POM, the plot of Na+K vs. Cl (Figure 6g) shows that most of the values fall along and adjacent to the equiline, except a few values deviating from the line, suggesting that most of the alkali ions are balanced by the chloride ions. As observed in the PRM plot of Ca+Mg vs. HCO_3+SO_4 (Figure 6h), the balancing of these anions over the alkaline earth metals is almost complete with few values falling away from the line. Moreover, it could be seen that the alkali excess in Figure 6a, and the alkaline earth metal excess in Figure 6b are well balanced by the HCO_3+SO_4 and Cl anions, respectively. Furthermore, this pattern could be seen in the POM values, too (Figure 6g and h).

During PRM, among the alkalis, Na is dominant and the concentration of potassium is apparently low. The natural source of potassium in water usually originates from chemical weathering, and subsequent dissolution of minerals of local igneous rocks such as feldspars (orthoclase and microcline), mica and sedimentary rocks as well as silicate and clay minerals [24]. Since these minerals are not abundant in the study area, potassium concentration in these waters is only 1/10th of the concentration of sodium; also, the low contribution of K may be due to the greater resistance of K to weathering and its fixation in the formation of clay minerals [25]. The high ratio of Na+K vs. Z^+ (Fig 6c and i) suggests that silicate weathering may, to some extent, contribute to the total cations [25]. In POM, the concentration of sodium predominates over that of potassium. Cl^- ion concentration in groundwater normally arises from three sources viz., ancient seawater entrapped sediments, solution of halite and related minerals in evaporate deposits, and solution of dry fallout from the atmosphere, especially in arid regions [26]. The high concentration of chloride in the study area does not seem to arise from the above factors, but it may be caused by anthropogenic activities, and also from the leaching of saline residues of the soil by the action of rainwater during POM [27].

4.4. Suitability for Irrigation

Irrigational suitability of groundwater in the study area was evaluated by different parameters such as EC, SAR, RSC, USSL classification, Na%, and Wilcox diagram. The excessive total content of soluble salts such as Na affects the suitability of groundwater for irrigation by its exchangeable capacity to Ca and Mg. If the percentage of Na^+ to $[Ca^{2+}+(Mg^{2+}+Na^+)]$ is more than 50% in irrigation waters, calcium and magnesium exchange with sodium, thus causing deflocculation and affects the permeability of soils [2] and the texture makes the soil hard to plough and unsuitable for seedling emergence [28]. The EC and Na concentration are important to classify the irrigation water. According to Richards [29], the irrigation water is classified into four groups such as low (EC = <250 µS/cm), medium (250–750 µS/cm), high (750–2,250 µS/cm), and very high (2,250–5,000 µS/cm) salinity. High EC in water leads to formation of saline soil, whereas high Na content in water causes alkaline soil. The sodium or alkali hazard in the use of water for irrigation is expressed by determining the SAR, and it was estimated by the equation:

$$SAR = Na/ [(Ca + Mg)/2]^{0.5}$$

Units are expressed in milliequivalent per liter

The SAR values indicate the relative proportion of Na to Ca and Mg. The calculated values of SAR in the study area vary between PRM and POM as 0.35-5.58 and 0.21-4.93 respectively (Table 2). According to SAR values, all the samples in PRM and POM are suitable for most types of crops and soils. Groundwater of the study area was classified based on salinity hazard (EC) and SAR which is given in table 3. It is found that 14% (PRM) and 25% (POM) of samples are considered as very high salinity and the water class is poor. High salinity and exchange with sodium, thus causing deflocculation and impairment of the tilth and permeability of soils [2]. The irrigation suitability of the groundwater was also assessed by plotting the data on the USSL (US Salinity Laboratory of the Department of Agriculture) diagram [29]. According to USSL, low salinity water (200mg/l) may be used for all the soil types. The groundwater of the study area falls into good to moderate category (Figure 7). Overall 85% (PRM) and 74% (POM) of samples fall in C1S1 and C2S1 fields indicating of low to medium salinity and low alkalinity water, which can be used for irrigation. Moreover 15% (PRM) and 25% (POM) of samples fall in C3S1 field indicating high salinity and low alkalinity hazard, which may not have appreciable sodium hazard.

Sodium can lead to the formation of alkaline soils combined with carbonate, while forms saline soils combined with chloride. Both soils do not support for plant growth. An alkali soil has an unfavourable structure, puddles easily and restricts the aeration. Further, the high sodium saturation directly causes calcium deficiency. Na% was calculated using the following equation.

$$Na\% = (Na \times 100)/ (Ca^{2+} + Mg^{2+} + Na + K)$$

A sodium percentage more than 60% is considered unsafe for irrigation [9]. The values for the Na % in the study area range from 6–89% and 15-91% in PRM and POM seasons respectively. About 27% (PRM) and 17% (POM) of the samples are higher than 60% Na and the remaining are within the recommended limit. Calculated Na% for the groundwater of present study region is plotted against specific conductance in Wilcox diagram (Figure 8) [30]. According to this plot, 96% of samples during PRM 95% of samples during POM are classified as excellent to permissible; 2 samples during PRM and 3 during POM are permissible to doubtful; and only 1 sample located near Andikuppam outlet in the eastern part of the study area, at Station 12 is doubtful to unsuitable category during PRM and POM.

The effect of bicarbonate ion concentration on the water quality is based on the residual sodium carbonate (RSC) concept by Eaton [31], where waters having >2.5 (meq/l) RSC are unsuitable for irrigation, 1.25–2.5 are marginal and <1.25 are safe waters. The residual sodium carbonate (RSC) is obtained on computation by the following equation:

$$RSC = (CO_3 + HCO_3) - (Ca^{2+} + Mg^{2+})$$

Where, ionic concentrations are considered in milliequivalents per litre. Based on this criterion, all the samples during both seasons are considered safe for irrigation based their low RSC values.

Suitability of groundwater for irrigation purposes was also assessed using the criteria shown in table 3. A comparison of TDS values with irrigation standards shows that 76% during PRM and 71 % during POM is considered class I, which is excellent to good category, whereas 1% in PRM and 8% in POM is considered class II which are suitable for permeable soil [20]. The Cl content of water samples suggests that 17% in PRM and 5% in POM are of Class II which may be injurious to crops. As per Cl and EC comparison 0-1% of samples during PRM and 1% of samples during POM are unfit for the irrigation purpose. The overall comparison between various suitability assessments show that only one sample (E12) is highly not suitable for irrigation.

The deficiency or excess of certain trace elements in irrigation water can retard growth and metabolic activities. Hence, neither the nutrient value nor the toxicity of trace elements in irrigation water can be ignored. Average and range of heavy metals in surface water bodies around the Neyveli mine-industrial complex and groundwater were compared with the average in the world's rivers [32] and irrigation water quality standards [33-34]; all values in mg/l (Table 4). Accordingly the average concentrations of Mn, Cr, Zn and Ni in surface waters exceed the recommended limits, whereas Pb, Cu, and Fe were well within the permissible limits. The source for the maximum concentration in the surface water bodies is the coal-based thermal power plant [35]. But the average concentration of trace metals in groundwater samples fall within the permissible limit, with the exception of Nickel which is recorded higher than the permissible limit.

Table 2: *Water quality classifications of the groundwater for irrigation based on SAR, EC, and RSC values*

SAR Range	EC	Water Class	PRM - Sample Number (%)	POM - Sample Number (%)	Salinity Hazard	Irrigation Suitability
<10	250	Excellent	1, 2, 5, 8, 23-27, 30-33, 35-37, 41-43, 60, 62, 64-68, 70 (35)	1, 2, 5, 6, 8, 9, 23-27, 29-33, 35, 36, 38, 41-43, 46, 47, 49, 60, 62,64-68, 70 (43)	Low	
10-18	251-750	Good	3,4,6,7,9-11, 13,14, 16-18,20-22,28,29,34,38-40,44-47,49,51-57, 61, 63, 69, 71, 75, 76 (51)	3,4,7,10, 11, 14, 17, 20, 28, 34, 39, 40, 44, 45, 52, 54, 55, 57, 59, 61, 63, 69, 71, 77 (31)	Medium	
18-20	751-2250	Fair	12, 15,19,48,50,58-59,72-74,77 (14)	13, 15, 16, 18, 19, 21, 22, 37, 48, 50, 51, 53, 56, 58, 72-76 (25)	High	
>20	>2250	Poor	- (0)	12 (1)	Very High	
Based on SAR Only						
1-10	Excellent		1-77 (100%)	1-77 (100%)		Suitable for all types of crops and soil except for those crops sensitive to Na
11 – 18	Good		-	-		Suitable for coarse textured or organic soil with permeability
19 – 26	Fair		-	-		Harmful for almost all soil
>27	Poor		-	-		Unsuitable for irrigation
Based on RSC						
< 1.25			1-77 (100%)	1-77 (100%)		Safe
1.25-2.5			-	-		Marginal
>2.5			-	-		Unsuitable

Table 3: *Irrigation Suitability of groundwater of the study area with different constituents*

Parameters	Class of Water I			Class of Water II			Class of Water III		
	Range	No of Samples (%)		Range	No of Samples (%)		Range	No of Samples (%)	
		PRM	POM		PRM	POM		PRM	POM
TDS (ppm)	0 – 700	76 (99)	71 (92)	700 – 2000	1 (1)	6 (8)	> 2000	-	-
SO_4 (ppm)	0 – 192	63 (82)	67 (87)	192 – 480	14 (18)	10 (13)	> 480	-	-
Cl (ppm)	0 – 142	63 (82)	72 (94)	142 – 355	13 (17)	4 (5)	> 355	1 (1)	1(1)
Ec (mS)	0 – 0.75	66 (86)	57 (74)	0.75 – 2.25	11 (14)	19 (25)	> 2.25	0	1(1)
Suitability for irrigation	Excellent to good			Good to Injurious			Unfit		

Table 4: *Average values of trace metals in surface and groundwater around the Neyveli mine-industrial complex compared with the average in the world's rivers [32] and irrigation water quality standards [33-34]; all values in mg/L*

Elements	World River (avg.)	Irrigation Water Standards	Study area (Average)			
			Surface water (N=2)		Groundwater (N = 77)	
			PRM	POM	PRM	POM
Fe	0.04	5.0	4.44	4.93	1.04	1.37
Mn	0.007	0.2	0.40	0.41	0.08	0.12
Cr	0.001	0.1	0.45	0.47	0.04	0.04
Cu	0.007	0.2	0.12	0.12	0.13	0.11
Pb	0.001	5.0	1.34	1.36	0.01	0.01
Zn	0.02	2.0	0.35	0.39	0.27	0.20
Ni	0.0003	0.2	0.63	0.53	0.62	0.46

5. Conclusion

Based on this study on quality of groundwater, it was found that Na content was dominant among cations and Cl among anions for both seasons. The variation of ions is observed except for pH, Mg, and phosphate, suggesting that the effect of monsoons is minimal on these ions. The results also suggest that there is no significant pollution of groundwater, except at a few stations. The type of water that predominates in the study area is $CaNaHCO_3$ type during both seasons of the year 2006, based on hydrochemical facies. The suitability of water for irrigation is evaluated based on SAR, %Na, RSC and salinity hazards. Most of the samples in study area are in the suitable range for irrigation purpose either from SAR, % Na or RSC values. About 85% (PRM) and 74% (POM) of the samples are grouped within C1S1 and C2S1 in both pre- and post-monsoon seasons, which is more suitable for irrigation. Remaining samples of groundwater needs better drainage to overcome salinity problems. Most of the samples (~99%) in the study area fall in the suitable range for irrigation purpose from USSL diagram. Even though some of the individual samples show higher concentration of trace metal the overall average values are within permissible limit of the standards, except Nickel content in the groundwater of the study area.

Figures

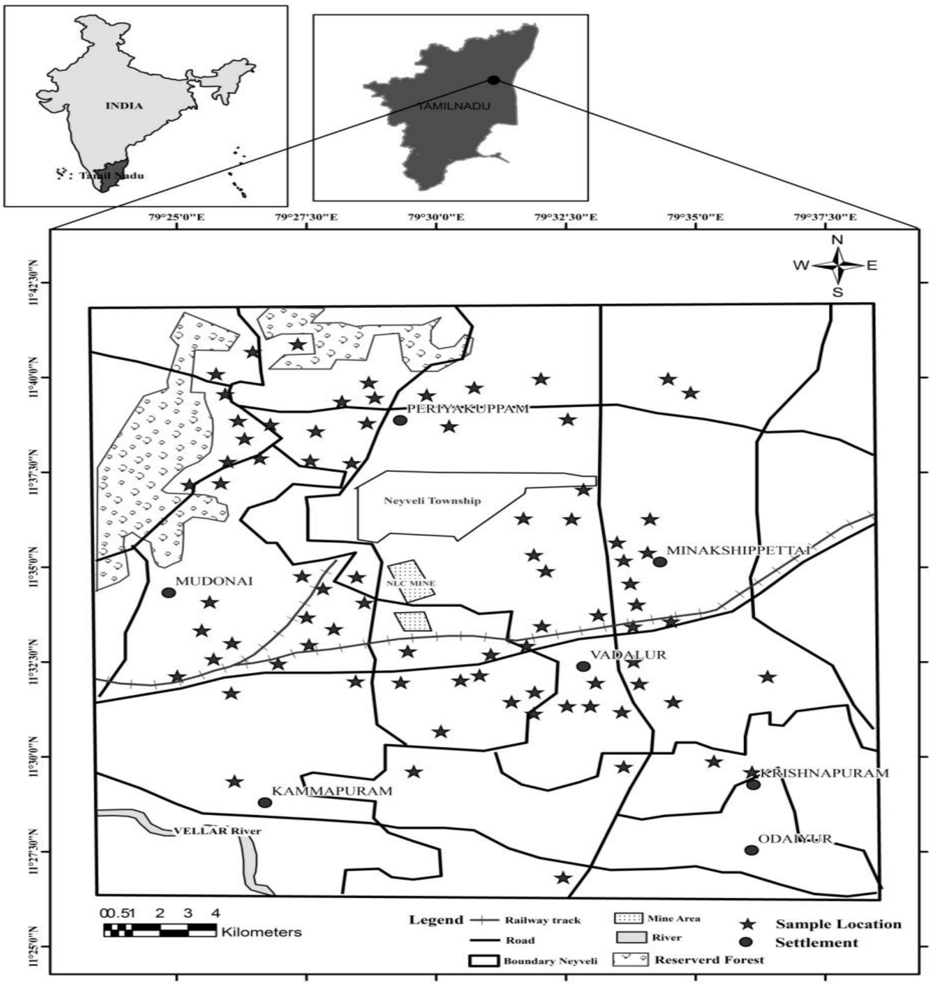

Figure 1: *Location map of the study area*

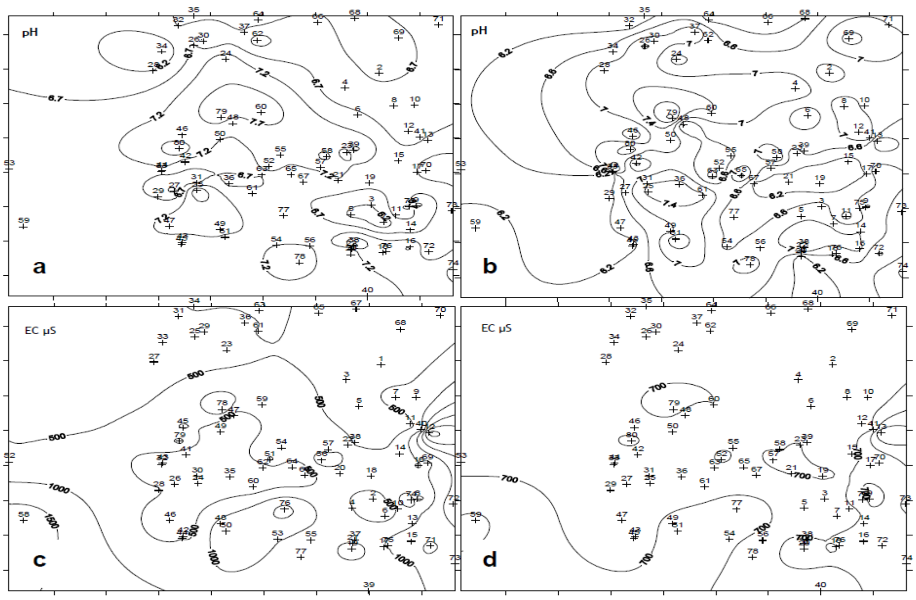

Figure 2: *Spatial distribution of pH and EC in the groundwater of the study area*

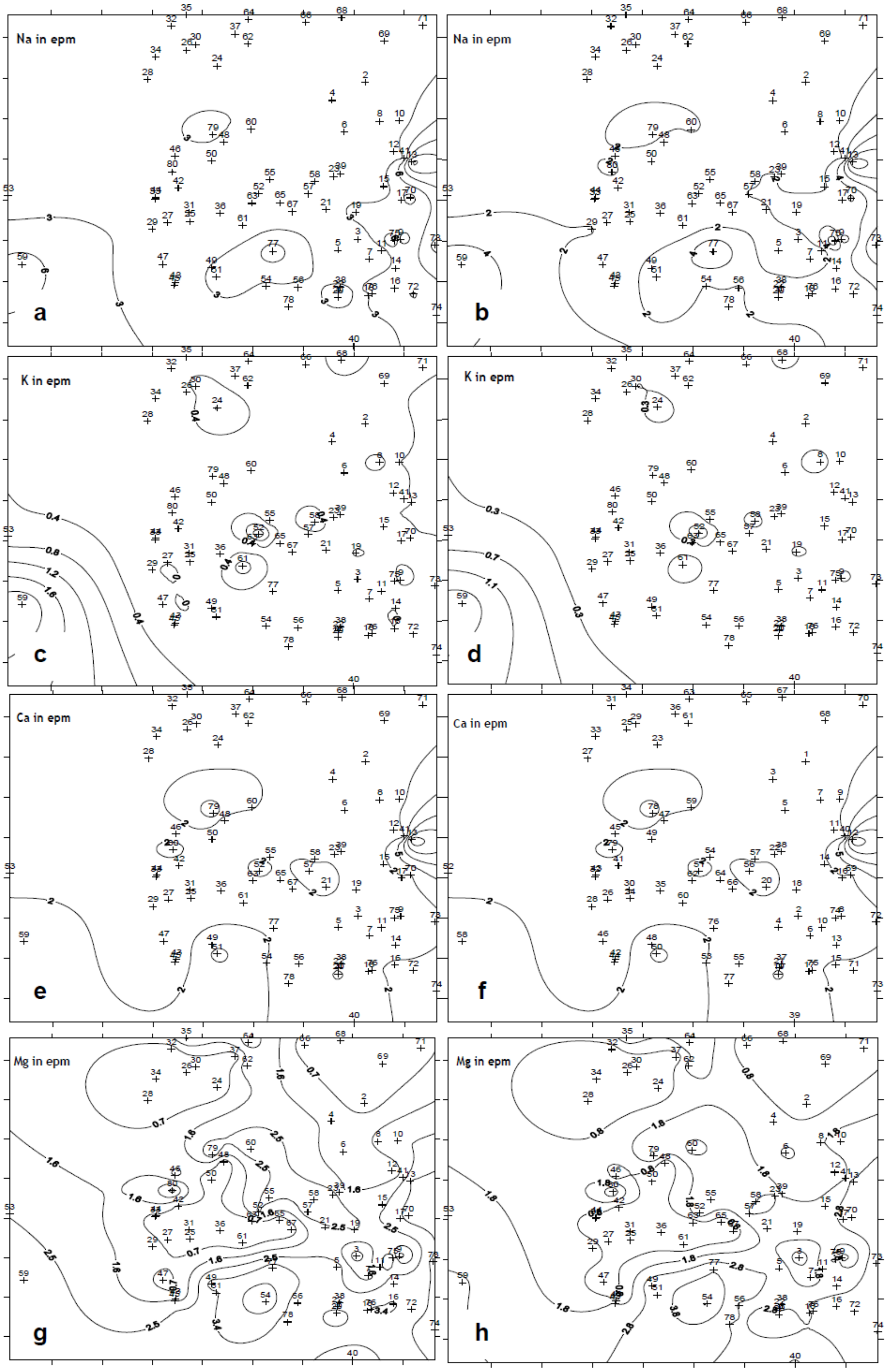

Figure 3a-h: *Spatial distribution of cations in the groundwater of the study area*

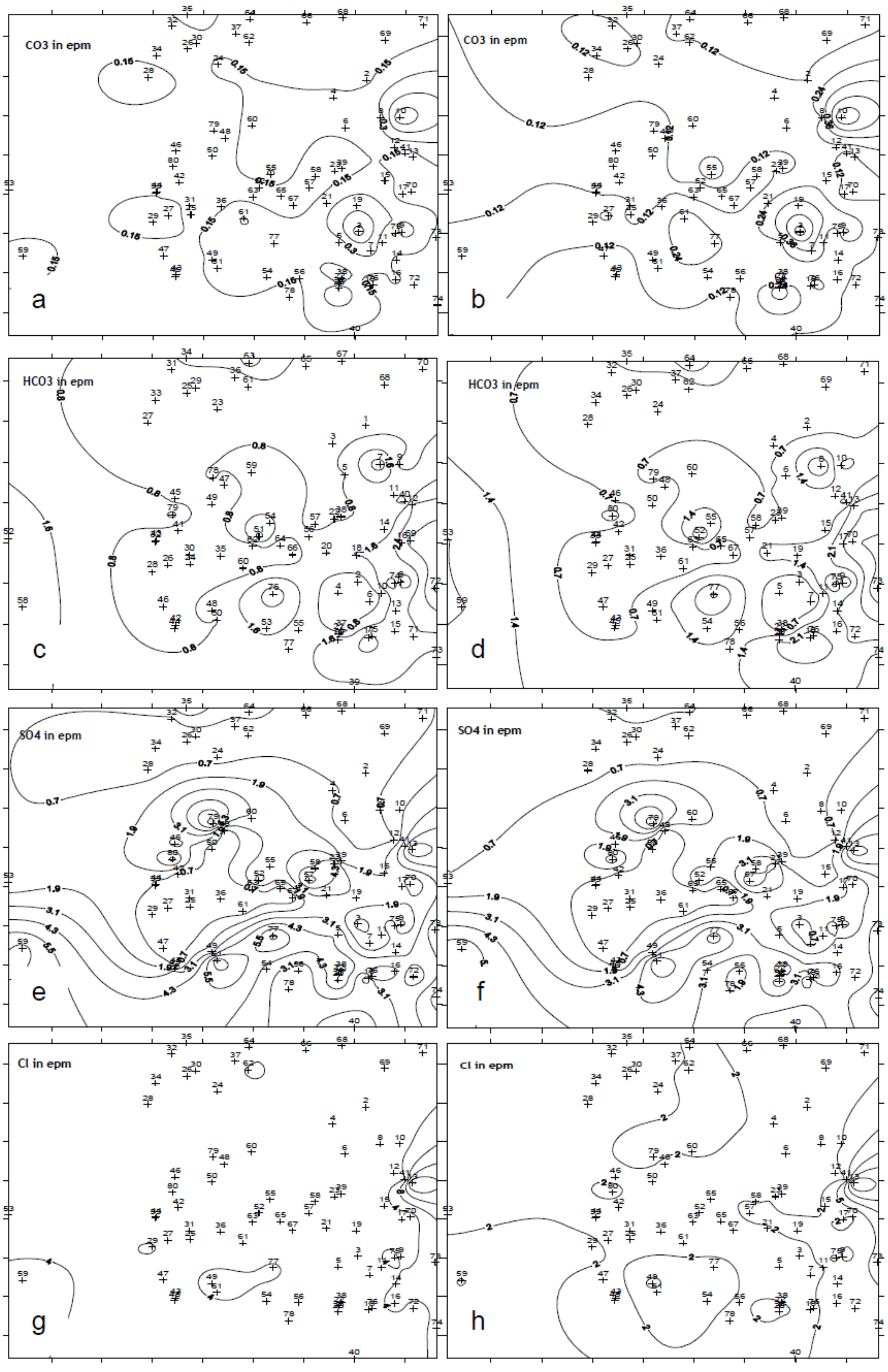

Figure 4a-h: *Spatial distribution of anions in the groundwater of the study area*

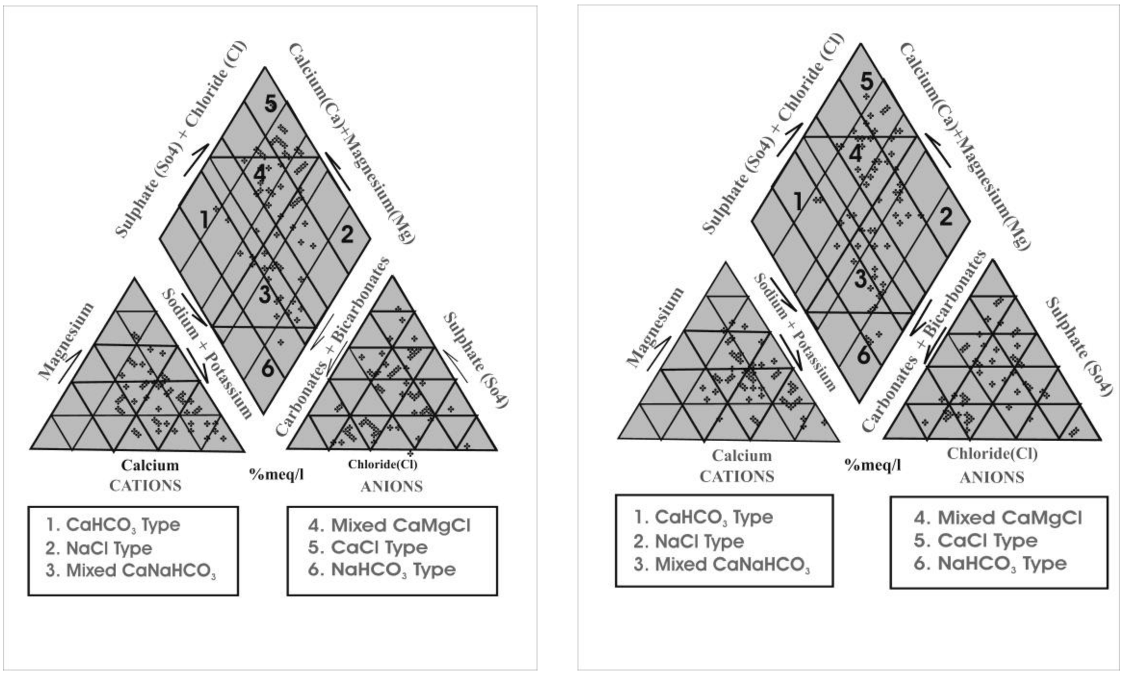

Figure 5: *Piper trilinear diagram for hydrogeochemical facies for groundwater of the study area (a.PRM; b.POM seasons)*

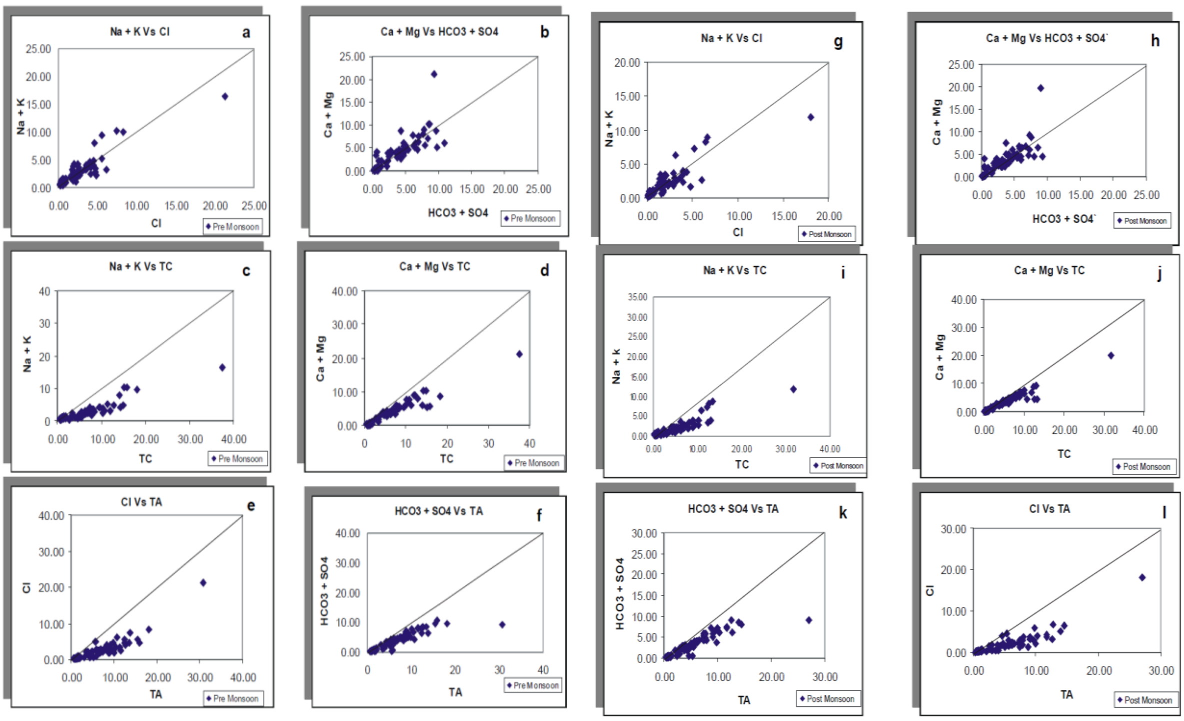

Figure 6a-l: *Equiline diagrams of the chemical parameters for the groundwater of the study area (a-f PRM; g-l POM)*

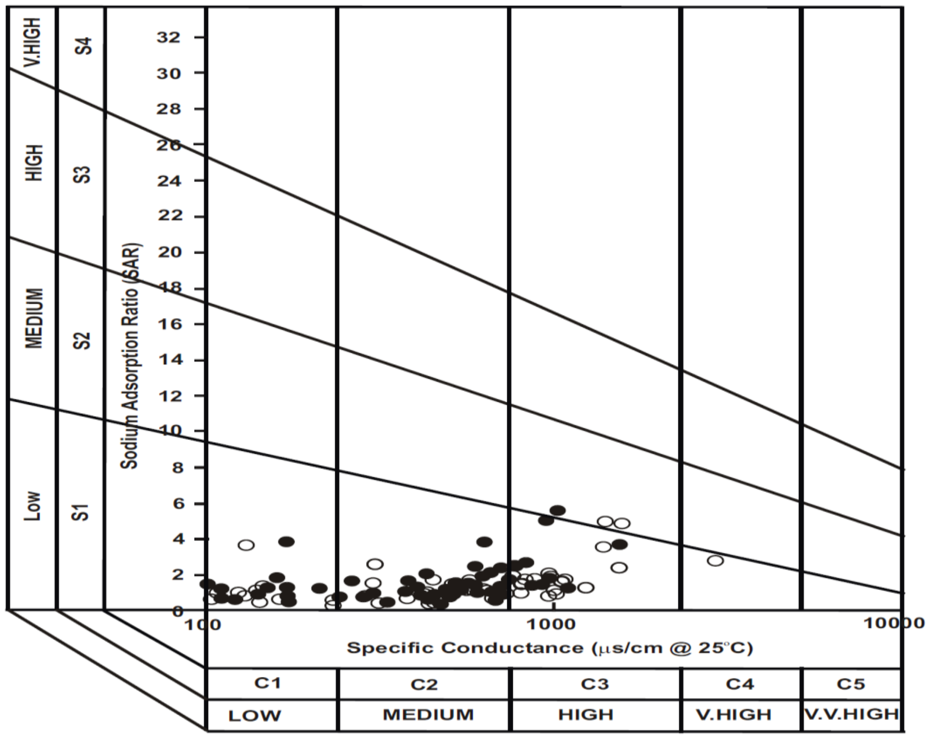

Figure 7: *USSL classification of groundwater samples (filled circle – PRM; open circle – POM)*

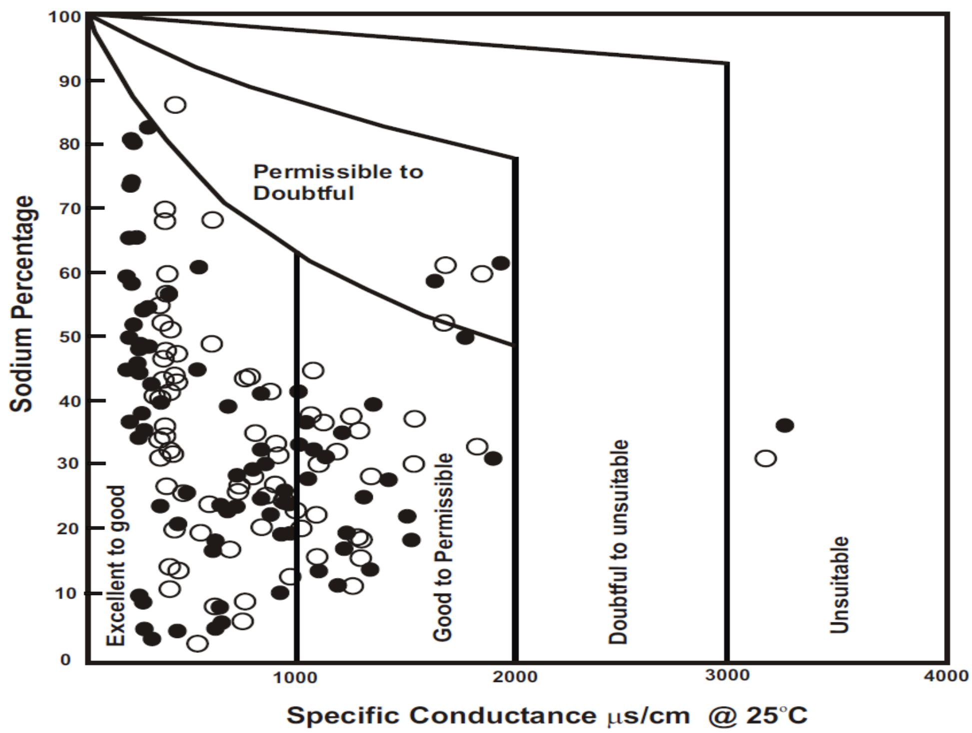

Figure 8: *Irrigational suitability of groundwater in the study area (filled circle – PRM; open circle – POM)*

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