Chapter – VI

SPATIAL AND TEMPORAL ASSESSMENT USING GEOGRAPHIC INFORMATION SYSTEM

6.1 INTRODUCTION

Understanding the spatial distribution of data from phenomena that occur in space constitute today a great challenge to the elucidation of central questions in many areas of knowledge, be it in health, in environment, in geology, in agronomy, among many others. Such studies are becoming more and more common, due to the availability of low cost Geographic Information System (GIS) with user friendly interfaces. These systems allow the spatial visualization of variables such as individual point and non-point pollution sources in a region using maps. To achieve that it is enough to have a primary database and a geographic base (like a map of the location or boundary basin), and the GIS is capable of presenting a colored map that allows the visualization of the spatial pattern of the phenomenon.

A Geographic Information System is a computer system for managing spatial data. The word geographic implies that location of the data items are known or can be calculated in terms of geographic coordinates. The word information implies that the data in a GIS are organized to yield useful knowledge, for instance, as coloured maps and images, statistical graphics, tables and various on screen responses to interactive queries. The word system implies that a GIS is made up of several interrelated and linked components with different functions, GIS arose from the need to incorporate the management of graphic and textual information into a single system. In GIS, the linking of graphic information in the form of a digital map, with textual information in the form of a tabular database, produces an “intelligent” or thematic map. Thus, a GIS have functional capabilities for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modeling and output. A GIS consists of a
package of computer programs with a user interface that provides access to a particular function. The user may control GIS operations with a graphical user interface (GUI), or by means of a command language, consisting of program statements that run in sequence and depict type of operations. GIS has been defined by many ways, and by many people, depending on their backgrounds and viewpoints. The definitions also change as technology and applications develop with time. “A GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex planning and management problems”. National centre has accepted this for geographic information and analysis (GSI 2007).

This simple but extremely powerful and versatile concept has proven invaluable for solving many real world problems from tracking delivery vehicles, to recording details of planning applications, to modeling global atmospheric circulation. Geographic information contains either an explicit reference such as latitude and longitude or national grid coordinate. GIS is a general purpose technology for handling geographic data in digital form. Its abilities include: preprocessing data into a form suitable for analysis, supporting spatial analysis and modeling directly, and post processing results (Goodchild 1993). For water resources problem solving, both a spatial representation of the system and an insight into water resource problems are necessary. GIS can represent the geo-referenced characteristics and spatial relationships of systems, but predictive and related analytical capacities are more useful and necessary for solving complex water resources planning and management problems (Walsh 1992).

Increasing public concern about water quality is a major trend. It is well known that Point (PS) as well as Non-point (NPS), or diffuse, sources of pollution are
recognized to be the leading causes of water body impairment. PS loading originates from confined areas, such as discharge pipes in factories or sewage plants. Storm water runoff and percolating water draining residential, commercial, rural, and agricultural areas carry NPS loading where many everyday activities add polluting substances to the land. Historically, most pollution control programmes have initially dealt only with PS pollution; however, all over the world and for several decades, a large percentage of water pollution has been recognized as originating from many NPSs (Novotny 1999). Typically, in less developed countries, PSs such as sewage from urban areas and NPSs such as sedimentation from deforestation or agricultural practices are the main components of pollution. In developed countries, runoff from agriculture and urban sources are the leading causes of non point pollution. There is also evidence of excessive water pollution in the U.S.: coastal environments and inland streams are showing typical characteristics of eutrophication, such as high levels of nutrient concentrations causing abnormal growth of algae and other organisms in the water and the consequent unbalanced depletion of oxygen (USEPA 1999a & 2000).

Major model components include weather, hydrology, soil temperature, plant growth, nutrients, pesticides, and land management. A complete description of the various components can be found in (Arnold et al 1998). Geographical Information System (GIS) was first considered as a powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a particular set of purposes (Burrough and McDonnell 1998). GIS is a general-purpose technology for handling geographic data in digital form. Its abilities include: preprocessing data into a form suitable for analysis, supporting spatial analysis and modeling directly, and post processing results (Goodchild 1993).

The control and management of water quality, particularly for impaired streams where NPSs are the overwhelming sources, would require outrageously expensive
monitoring activities. The modeling alternative requires the description and understanding of several hydrologic phenomena with intrinsic spatial and temporal variation. Mathematical, hydrology based, distributed parameter simulation models and GIS technology provide a potential synergy that appears to be the key feature for an effective understanding and interpretation of these complicated hydrologic processes connected with water quality assessment. There are diverse elements promoting the development of such systems for water resources applications (Wilson et al 2000). Among these, the fundamental elements for our research are: (i) GIS are developed to the level that the bi-directional process of data transfer toward and away from the model can be fully automated and enriched with interactive analysis tools for understanding the physical system and judging how management actions might affect that system's management; and (ii) the growing availability and quality of disparate supporting datasets provide convenient descriptions of important hydrologic variables that are related to chemicals, soils, climate, topography, land cover, and land use.

Water quality is an important factor for human health and quality of life. This has been recognized many years ago. Therefore, in Sweden, large investments were made in water treatment systems for industrial and residential areas in the past in order to reduce the output of toxic chemicals, organic matter and nutrients. Obvious point sources of pollution could be found and were controlled. For further increase of water quality, it is also necessary to reduce the non-point source pollution. This is more difficult because these sources are not discrete places but diffuse areas somewhere on the Earth’s surface. To eliminate them too, a method is needed that can find these critical areas which could be possible sources of non-point pollution. These elements will ultimately increase the reliability of decision support tools on a watershed scale, the hydrological unit where NPSs and PSs are required to be correctly factored into an effective management system, as all human and natural activities upstream have the potential to affect water quality and quantity downstream. This paper describes the
development of such an ArcMap/Info, which utilizes the ArcGIS spatial distribution model and was designed to support the combined watershed assessment and analysis of NPS and PS pollution loading.

6.2 GLOBAL POSITIONING SYSTEM

The Global Positioning System is a satellite-based navigation and surveying system, launched and controlled by the U.S Department of Defense (DOD), for determination of precise position and time using radio signals from the satellites, in real-time or in post-processing mode. The technique overcomes the numerous limitations of terrestrial surveying methods, like the requirement of inter-visibility of surveying stations, dependability on weather, difficulties in night observations, etc. The Global Positioning System (GPS) yields positions of survey points on a global reference surface called World Geodetic System 84 (WGS 84). The use of GPS to capture geo information has helped researchers and planners to interpret data about a particular region with regards to the natural resources present (Garg 1999; Srivastava 2001). These advantages over the conventional techniques make GPS the most promising surveying technique of the future. The well-established high accuracy is achievable with GPS in positioning of points separated by few hundreds of meters to few hundreds of kilometers. This unique surveying technique has found important application in diverse fields. In the present study, GPS (Leica G20 USA) is used to collect the field samples and represent globally.

6.3 GIS APPLICATION

In the present research work, the GIS (ArcGIS 9.2) are used to prepare all kinds of spatial maps. Initially, the base map is prepared by using the Survey of India toposheets No. 58 L/2, G/16, H/5, H/6, H/9, H/10, H/10, H/13, and H/14 in the scale of 1:50,000. It provides basic or fundamental information on the study region such as reserved forest, elevation, contouring, local communications network for accessibility,
drainage systems, urban distribution etc. Followed by, the other thematic maps namely geology, geomorphology, structure etc. In the present work, the technique applied three main stages: i.e., i) digitization ii) GIS map manipulation and iii) GIS analysis. The Tamiraparani river basin boundary map, the sampling points was digitized using GIS 9.2 package. All the feature of each digitized lines are taken as x, y coordinates and the value (concentration) of each point was coded as z. The digitized points were stored as vector file of polygon format and finally transformed into raster format. Water quality maps are presented for the concentrations of the following determinands: total dissolved solids, sodium, bicarbonate, sulphate, chloride, nitrite, orthophosphate, and pesticide residues in surface water and sediment samples in different seasons were illustrated for the river basin.

6.3.1 Seasonal and temporal distributions of total dissolved solids

The spatial and temporal modeling of total dissolved solids (TDS) for both monsoon and summer seasons are given in Figs 6.1 and 6.2. The TDS is an imprint of the ionic strength of the surface water. The seasonal changes in the calculated dissolved solids in Tamiraparani river basin were illustrated using ArcGIS output. The TDS has been classified into nine different ranges from <60.0 mg l$^{-1}$ to >818.0 mg l$^{-1}$ during summer season are high values than the monsoon season. The second phase is classified in the ranges of 196.4 to 360.9 mg l$^{-1}$ and is dominant in the stream region during the monsoon season and it is given Fig 6.1. There is a consistent down stream increase in the TDS concentration ranging from 690.3 to 818.0 mg l$^{-1}$. In this same condition is obvious that in the summer season higher ionic strength is prevalent due to evaporative losses and low fresh water discharge. The TDS is higher in the downstream region, which is mainly attributable to anthropogenic inputs in addition to the intrusion of the river with the seawater. In the present study, the observed TDS concentration is compared with other major Indian (Subramanian 2004) and world rivers. The TDS in the Tamiraparani river is analogous to the rivers draining through peninsular region.
such as the Cauvery, Krishna and Narmada is higher than the Himalayan rivers Ganges and Brahmaputra.

6.3.2 Seasonal and temporal distributions of Sodium

The sodium concentration ranges of 1.4 to 19.3 mg l\(^{-1}\) and 2.5 to 90.6 mg l\(^{-1}\) during monsoon and summer seasons, respectively. The high concentrations of sodium scrutinize in the downstream region as compare to upstream and downstream during monsoon season due to rain, halites, saline/alkaline soils, anthropogenic activities, and silicate. The high value was observed during summer due to evaporite processes and may influences seawater intrusion in the downstream region. In the site (S7) was shown the higher (11.5 to 13.5 mg l\(^{-1}\)) concentration as compare to other sites in the upstream due to tourism activities and untreated municipal sewer mixing into the river. Figs 6.3 and 6.4 shown in the river catchment area was observed low amount of sodium particularly upstream region sites S1, S5, S6, S8, S9, and S10 during both season to increasing river order also increasing sodium concentration.

6.3.3 Seasonal and temporal distributions of Bicarbonate

Figs 6.5 and 6.6 were illustrating in spatial and temporal distribution of bicarbonate concentration ranges of 15.6 to 256.2 mg l\(^{-1}\) and 15.1 to 109.8 mg l\(^{-1}\) during monsoon and summer seasons, respectively. The higher concentration of bicarbonate (96.0 to 109.0 mg l\(^{-1}\)) was observed in the upstream region particularly at Tenkasi (S7) site due to anthropogenic activities such as municipal waste and natural weathering processes such as silicates, carbonates weathering, and carbon dioxide during both the seasons. Low concentration illustrates in the catchment region particularly at Papanasam, Kuttralam, Ambasamuthiram and Gadana sites during monsoon and summer seasons and moderate level (116.3 to 143.8 mg l\(^{-1}\)) are present at downstream region at S19 and S20 sites during summer season.
Fig 6.1 Total Dissolved Solids in monsoon season

Fig 6.2 Total Dissolved Solids in summer season
Fig 6.3 Sodium concentration in monsoon season

Fig 6.4 Sodium concentration in summer season
6.3.4 Seasonal and temporal distributions of Sulphate

The sulphate concentration was observed in the ranges of 39.4 to 126 mg l\(^{-1}\) and <41.7 to 359.9 mg l\(^{-1}\) during monsoon and summer seasons respectively. Figs 6.7 and 6.8 were illustrating in upstream region particularly in Tenkasi have observed high concentrations of sulphate (320.3 to 359.9 mg l\(^{-1}\)) during summer and in the S3 and S11 sites during monsoon season have observed high concentration of sulphate (117.0 to 126.0 mg l\(^{-1}\)) in the river basin are due to rock weathering processes and anthropogenic activities such as fertilizers, mining of pyrites, atmospheric deposition from fossil fuel burning it could be influencing the high concentrations of sulphate in the river basin. At the same time in the catchment area S1, S2, S3, S4, S5, S8, S9, S10 and S11 sites were observed low concentration in the range of <41.7 mg l\(^{-1}\) during summer season.

6.3.5 Seasonal and temporal distributions of Chloride

The chloride was observed in the ranges from 2.64 to 69.7 mg l\(^{-1}\) and 3.1 to 155.7 mg l\(^{-1}\) during monsoon and summer seasons, respectively. Figs 6.9 and 6.10 were illustrating in the catchment area of the basin during monsoon and summer seasons respectively. The chloride concentration was obtained in the less range of (<8.5 mg l\(^{-1}\)) and maximum concentration (141.8 to 159.7 mg l\(^{-1}\)) during summer season in the upstream region and midstream region also have high concentrations (53.7 to 68.6 mg l\(^{-1}\)) was observed during monsoon season particularly Seranmahadevi, Tirunelveli, Valamadu, Srivaikundam region and Eral, Agaram and Mulukkadu sites in the downstream region as compared to other sites of the river basin are due to rocks halites and anthropogenic activities. In the downstream sites, S19 and S20 were shown high concentrations of chloride are observed due to it could be seawater intrusion during the summer season.
Fig 6.5 Bicarbonate concentration in monsoon season

Fig 6.6 Bicarbonate concentration summer season
Fig 6.7 Sulphate concentration in monsoon season

Fig 6.8 Sulphate concentration in summer season
Fig 6.9 Chloride concentration in monsoon season

Fig 6.10 Chloride concentration in summer season
6.3.6 Seasonal and temporal distributions of Nitrite

The nitrite concentration ranges from 0.3 to 3.6 µg l\(^{-1}\) during monsoon season. The high concentrations have shown in the Figs 6.11 and 6.12 shown the Tenkasi and Tirunelveli sites as compared to other sites due to the municipal, Industrial waste and immense agricultural activities into the river basin, and low concentration was observed in the upstream river catchment region due to damming activities may deposits the minerals in the region. In Tenkasi site was observed in high concentration of nitrite in the range of 41.9-47.0 µg l\(^{-1}\) during summer season are due to dense forest plant roots bacteria produces nitrite it may influencing the high concentration of nitrite and low nitrite was illustrates in the mid and downstream region in the ranges of < 5.8 µg l\(^{-1}\) are due to mainly river flora and fauna its may uptakes more nitrite contents for their growth in the river water and also damming activity.

6.3.7 Seasonal and temporal distributions of Orthophosphate

The orthophosphate concentration was observed in the ranges of 0.5 to 16.7 µg l\(^{-1}\) and 2.1 to 12.4 µg l\(^{-1}\) during monsoon and summer seasons, respectively. Figs 6.13 and 6.14 were illustrating the spatial analysis of orthophosphate in the river basin. The high orthophosphate concentration in the range of (13.2 to 16.7 µg l\(^{-1}\)) in the midstream and downstream regions particularly S12, S13, S14, S15, S17 and S18 sites due to fertilizer run-off from agriculture field, pesticides, industry effluents and cleaning compounds and natural sources including phosphate containing rocks and solid and liquid waste during monsoon season. The upstream region S5 site have high concentration of orthophosphate in the ranges of 11.3 to 12.4 µg l\(^{-1}\), and 3.7 to 6.2 µg l\(^{-1}\) in the mid and downstream region has in moderate levels and amount are observed in the catchment area such as S8, S1, S3, S5 sites due to in the region gets more rain fall and anthropogenic activities during summer season.
Fig 6.11 Nitrite concentration in monsoon season

Fig 6.12 Nitrite concentration in summer season
Fig 6.13 Orthophosphate concentration in monsoon season

Fig 6.14 Orthophosphate concentration in summer season
6.3.8 Seasonal and temporal distributions of ΣOCPs in the water and sediments

The environmental contaminations by pesticide residues are of great concern due to their toxicity, bioaccumulation and persistent nature. Organochlorine pesticides such as HCH (hexachlorocyclohexane) and DDT (dichlorodiphenyl-trichloroethylene), endrin, lindane and aldrin are among the most persistent and globally distributed organic pollutants. These pesticides are long-lived organic compounds that become concentrated as they move through the food chain and have toxic effects on reproduction and immunological function. Since the introduction of organochlorine pesticides in late 1930s, the residues of these compounds have been found in many parts of the World (Hattula et al 1978). Pesticides are unique in that they are purposefully released in to the environment to control the selected species. The chlorinated pesticides are now largely banned chemicals, which may still pose a threat to human health as well as the wider environment.

The organochlorine pesticides are chronic toxic substances in the environment having properties of non-degradability and bio-magnification. These organochlorine pesticides ender the environment through non-point sources namely agriculture. Hence, an attempt has been made to quantify as well as to understand the relationship between land use pattern and pesticide concentration in the river basin. Figs 6.15, 6.16 and 6.17, 6.18 are can observe the distribution pattern of agriculture land use (hectares) and the pesticide concentration (ng/l) in the surface water and sediment of the river basin during the study. In the upstream province, the agriculture land is covers between 1500 and 3000 hectares. In the midstream province, the cultivatable land area ranges between 3000 to 6000 hectares. In the present study, the ΣOCPs residues concentration in the surficial water of the Tamiraparani river is proportional to the agricultural land use pattern due to the upstream region recently abundant uses in the agricultural activities and physical and chemical properties of the OCPs. During monsoon season in the water samples were observed the ΣOCPs concentration ranges between 0.8 to 60 ng l⁻¹,
Fig 6.15 Organochlorine pesticide residues in water samples during monsoon

Fig 6.16 Organochlorine pesticide residues in sediment samples during monsoon
Fig 6.17 Organochlorine pesticide residues in water samples during summer

Fig 6.18 Organochlorine pesticide residues in sediment samples during summer
0.2 to 3.1 ng l$^{-1}$ and 0.4 to 3.8 ng l$^{-1}$ in the upstream, midstream and downstream region respectively. While the sediments sample was obtained the $\Sigma$OCPs concentration ranges between 165.1 to 543.5 ng g$^{-1}$, 164.5 to 1205.8 ng g$^{-1}$ and 733.2 to 1761.9 ng g$^{-1}$ in the upstream, midstream and downstream region respectively. The GIS approach ascertained new relationships between various constituents of surface water chemistry and other information about the region available in geographical presentation. This GIS based methodology was combined with ecological characterization of the receiving water bodies so that more site specific risk indices are developed.