CHAPTER – II
REVIEW OF LITERATURE

2.1 General

This chapter highlights the existing literature on the drainage basin system and its relationship between landuse and water quality (both river and groundwater). A systematical methodology is adopted to ensure the factors driving the complex mechanism in a basin. Such factors include general description, geological and geomorphological settings, morphometric analysis, landuse dynamics, soil erosion, water quality and related studies have been reviewed carefully. It also deals with various parameters of basin characteristics and elucidates how the perspectives of these parameters have modified throughout the year. The chapter is divided into six major sections and in each section, the present scientific problem prevailing in the study area has been compared with the literatures worldwide.

In the first section, the morphometric evaluation of different basins has been reviewed. The pioneer work on this aspect is critically examined including the latest technologies and computer aided techniques used for such evaluations have also been discussed. The second section deals with studies on landuse and land cover change analysis (LULC). The driving factors of landuse shift have also been reviewed. The third section has been devoted to the study of soil erosion. This section outlines the significance of soil erosion on water resources. The different techniques used in soil erosion mapping are also compared with each other. The fourth section is committed to water quality (both river and groundwater) and the factors affecting the quantity and quality of river and groundwater in different basins and special emphasis is given to its corresponding landuse. The fifth section focuses on the statistical relationship between landuse change on the water quality of both surface as well as groundwater and various
spatial statistical analyses and GIS tools used to understand the impact of landuse on water quality has been reviewed in this section. Finally, in the sixth section, a review of related studies conducted in the study area by other researchers has been evaluated and the need for the present study has been scrutinized.

2.2 Reviews on morphometric analysis

Morphometric analysis of a river basin is inevitable for river basin evaluation, watershed prioritization, and natural resources management. It describes the surface characteristics and provides information regarding the formation and development of topography and underlying geological structures since, the entire hydrologic and geomorphic processes occur within the watersheds. Drainage basins are the fundamental units of a fluvial landscape and a great amount of research has been focused on their geometric characteristics, including the topology of the stream networks, and quantitative description of drainage texture, pattern, shape, and relief characteristics (Abrahams, 1984).

Horton was the first to establish a quantitative method for analyzing the drainage networks in the early 1940s. Today, drainage morphometry tends to focus upon basin area, shape, length, and relief attributes, and on drainage density. Pioneering work of Strahler, (1952; 1957; 1964), Horton, (1932; 1945) are the basic foundation for morphometric analysis. Consequently, a number of books (Keller & Pinter, 1996; Bloom, 2002) have further propagated the morphometric approach of basin analysis. Hack, (1973) has founded the stream gradient index and stream profile analysis, which is another highlight in morphometric analysis.

Many hydrogeologists throughout the world have studied the morphometric analysis of different basins using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957) and using remote sensing (RS) and geographical information system (GIS)
techniques (Krishnamurthy et al., 1996; Nag, 1998; Rudraiah et al., 2008; Rao et al., 2010; Malik et al., 2011; Magesh & Chandrasekar, 2012). Since mid-1980s, with increased popularity of GIS technology and availability of Digital Elevation Models (DEMs), the potential of using DEMs in the studies of surface processes has been widely recognized (Wharton, 1994). New methods and algorithms have been developed to automate the procedure of terrain characterization (Hogg et al., 1993; Guth, 1995; Desmet & Govers, 1996).

Remote sensing data is quite effective for assessing the drainage pattern, landuse pattern and soil characteristics while GIS techniques can be used for manipulation and analysis of spatial information, thus providing a flexible environment for data handling (Jasmin & Mallikarjuna, 2011). Using SRTM data and GIS techniques is a speed, precise, fast and inexpensive way for calculating morphometric analysis (Farr & Kobrick, 2000; Smith & Sandwell, 2003; Grohmann, 2004; Grohmann, et al. 2007).

Magesh et al., (2012a) have developed an automated extraction tool for the analysis of basin morphometry and successfully applied in Tamiraparani sub-basin for evaluating its drainage characteristics. It was developed using ArcGIS model builder and it requires a DEM raster and a pour point as input data.

Sreedevi et al., (2005) have studied the drainage characteristics of the Pageru river basin, India using topographical maps and Landsat imagery to delineate groundwater potential zones. They found that the development of stream segment in the basin is more or less affected by rainfall and the erosional processes of fluvial origin have been predominantly influenced by the subsurface lithology of the basin. Al-Daghestani & Al-Maitah, (2006) have implemented the water harvesting techniques at sub-basin level based on morphometric analysis in Wadi Umm Al Quiffa basin, Jordan. Magesh et al., (2012b) have evaluated the morphometric characteristics of Chimmini and Mupily
watersheds in Thrissur district, Kerala using GIS techniques and found that both the watersheds are dominated by lower order streams and the development of stream segments are affected by rainfall and local lithology of the watershed.

Wilson et al., (2012) have studied the drainage characteristics of major watersheds in Aiyar and Karai Pottanar basin, central Tamil Nadu using remote sensing and GIS techniques. They found that the drainage networks of the region are subjected to strong structural control and it plays a major role in determining the fluvial landforms in a basin scale. Ganesh and Vasantha, (1988) have studied the morphometric characteristics of upper Vaigai basin, Tamil Nadu.

Jasmin and Mallikarjuna, (2013) have analysed the morphometric characteristics of Araniar river basin using remote sensing and geographical information system and also assessed the groundwater potential zones and marked suitable sites for artificial recharge structures.

Tamilenthi and Baskaran, (2012) have characterized the drainage pattern of the Cauvery river basin using Digital Elevation Model (DEM) and spatial technology. The study highlights that the basin is elongated in shape with low relief. Also, Nagabhushana and Govindaiah, (2012) studied the drainage characteristics of a compact block of eight sub-watersheds of the Cauvery basin with varied geological and geomorphological set up.

Nageswara Rao et al., (2010) have assessed the morphometric parameters of Gostani river basin in Andhra Pradesh using spatial information technology. They found that the basin is strongly elongated and have highly permeable homogenous geologic materials.

Manu and Anirudhan, (2008) have studied the drainage characteristics of Achankovil river basin in Kerala, which separates the Kerala Khondalite Belt (KKB) and Charnockite terrain. They found that the architecture of the basin is much influenced by the Achankovil Shear Zone (ASZ) and have a clear evidence of structural control.
Thomas et al., (2010) have analysed the morphometric aspects of Muthirapuzha watershed, a major tributary of river Periyar. The results indicate that the rainfall has a significant role in the drainage development and they also found that the asymmetry in the drainage distribution is correlated with the tectonic history of the Munnar plateau in the late Paleocene age.

Rekha et al., (2011) have analysed the morphometric parameters and prioritized the micro-watershed of Peruvanthanam sub-watershed in Manimala river basin, Kerala. The study reveals that the sub-watersheds has a complex structure with high runoff and low infiltration rate.

Thomas et al., (2011) have studied the drainage system of Pambar river basin using morphometric parameters. They highlighted the influence of climate on drainage characteristics and discussed the significance of morphometric analysis on the hydrological characterization.

Vincy et al., (2012) have studied the morphometric characteristics of sub-watersheds of Meenachil river basin in Kottayam district, Kerala using geographical information system. The study highlights that terrain exhibits dendritic to sub-dendritic drainage pattern and the mean bifurcation ratio indicates that both the sub-watersheds are within the natural stream system.

Magesh et al., (2013a) have analyzed the morphometric characteristics of Bharathapuzha river basin, Kerala using geographical information system. The study reveals that the DEM data coupled with geo-processing technique is a competent tool in morphometric analysis and can be used for basin management and other hydrological studies.

Joji et al., (2013) have delineated the Panamaram watershed of Kabani river basin using remote sensing and GIS. The study indicates that the drainage pattern is not much
influenced by geological structures. They also fitted the Hortonian model to estimate the bifurcation ratio, length ratio and area ratio but, they found that a second degree polynomial equation seems to be a good model rather than the Hortonian model.

Prasannakumar et al., (2013) have evaluated the terrain and geomorphometric parameters in the two major sub-watersheds in Attapady valley, Kerala using DEM and GIS analysis. They compared the morphometric and hypsometric measurements of both the sub-watersheds and found that both the watersheds are structurally complex and the denuded hills are undergoing severe soil erosion.

Morphometric analysis was also adopted for the purposes of integrated land and water resources management (Saxena & Prasad, 2008), groundwater studies (Mishra et al., 2011), soil erosion studies (Bagyaraj & Gurugnanam, 2011), landslide analysis (Chen & Yu, 2011), tectonic studies (Altin & Altin, 2011) and natural hazard vulnerability assessment (Rawat et al., 2011). In some studies, the characteristics of basin morphometry have been used to predict or describe the geomorphic processes such as prediction of flood peaks, and assessment of sediment yield (Baumgardner, 1987; Gardiner, 1990).

The application of geomorphic principles to flood potential has led to a noteworthy amount of research attempting to identify relationships between basin morphometry and stream flooding (Patton & Baker, 1976; Patton, 1988). Chorley, (1969) found that in homogeneous bedrock, bifurcation ratio influences the landscape morphometry and plays an important role over the “peakedness” of the runoff hydrograph.

Mishra et al., (1984) studied the effect of different topographic elements such as area, drainage density, form factor etc. with the sediment production rate of the sub-watersheds in the upper Damodar valley and concluded that increase of form factor reduces the sediment production rate. Morisawa, (1958) analysed the effect of different shape
parameters on runoff-rainfall ratios. It has been observed that the shape parameters showed a negative correlation with rainfall-runoff ratio.

Prioritization of sub-watersheds based on morphometric analysis of drainage basins using remote sensing and GIS techniques was attempted by Biswas et al., (1999). Nooka Ratnam et al., (2005) carried out check dam positioning by prioritization of micro-watersheds using Silt Yield Index (SYI) model and morphometric analysis using remote sensing and GIS in Midnapore district of West Bengal. Waugh, (1996) noted that the human significance of the bifurcation ratio is that as the ratio is reduced so the risk of flooding within the basin increases. It also indicates the flood risk is confined to certain part of the basin rather than the entire basin.

According to Rodda, (1969) the basin shape is of obvious importance in influencing the peak flow although, it is a feature that is difficult to express numerically. Strahler, (1964) noted that the shape of a drainage basin might conceivably affect the stream discharge characteristics. Long narrow basins with high bifurcations would be expected to have attenuated flood–discharge periods, whereas round basins of low bifurcation ratio would be expected to have sharply peaked flood discharges. Quantitative expression of drainage basin shape or outline form was made by Horton, (1932) through a form factor. On the other hand, Schumm, (1956) used an elongation ratio Rc, defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length to describe basin shape. Other indices of basin shape include Miller, (1953) circularity ratio, Horton’s form factor, and compaction coefficient. The above said indices can be better-evaluated using geospatial techniques for understanding the type of landform and their processes, drainage management and evolution of groundwater potential for basin planning and management. It is also useful for natural resources management at micro-level of any terrain for the sustainable development of river basins.
2.3 Reviews on landuse/land cover change

Humans have been modifying their environment since the age of colonization. They transformed the land cover to fulfill their needs for survival. The study on changing landuse and land cover has great significance for future land use planning as well as managing water resources. In this section, an attempt has been made to present a brief review of literature related to landuse studies around the world and within India. According to Turner et al., (1993), land-cover refers to the biophysical attributes of the earth’s surface and immediate sub-surface. It includes four variables namely, land, water, air, and man. On the other hand, landuse is a description of how people utilize the land for their needs by various management practices (Fisher et al., 2005; IPCC, 2000).

Proper utilization of land is essential for sustainable development. However, landuse often changes continuously because of changes in pattern and the extent of anthropogenic activities. According to Lambin et al., (2001), landuse and land-cover changes can affect the functioning of the earth’s system significantly and have a direct impact on the diversity of plants and animals worldwide. Moreover, such modification may alter the climate at local and regional levels as well as contribute to global climate change. To quantify the rate of landuse change on a global as well as on regional scale, a reliable technology is required. One such promising technology available at present is remote sensing. Over the past decade, remote sensing has played a vital role in landuse/land cover change detection. LULC change detection studies are gaining importance with the availability of a wide range of sensors operating at various imaging scales. Considerable research has been carried out on various components of LULC change including their reliability and accuracy assessment.

“Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact
with an object, area, or phenomenon under investigation” (Lillesand & Kiefer, 1987). It provides a large variety and amount of data about the earth surface for detailed analysis and change detection with the help of various space borne and airborne sensors. It presents powerful capabilities for understanding and managing earth resources. Remote sensing has been proven to be a very useful tool for LULC change detection (Matinfar et al., 2007).

A large number of change detection techniques have been developed since the advent of the orbital system (Lillestrand, 1972). Byrne et al., (1980) have shown that Landsat multispectral data can be used to identify LULC changes very effectively. Successful use of satellite remote sensing for LULC change detection depends upon an adequate understanding of landscape features, imaging systems, and methodology employed in relation to the aim of the analysis (Yang & Lo, 2002). Various remote sensing data products over time have often been incorporated into historical landuse information (Acevedo et al., 1996; Clarke et al., 2002; Meaille & Wald, 1990).

Classifying the satellite images to extract the landuse/land cover theme is one of the major steps in this type of study. Moreover, successful utilization of remotely sensed data for LULC studies demands careful selection of an appropriate dataset and image processing techniques (Lunetta, 1998). The most common image analysis for extracting LULC is digital image classification. The purpose of image classification is to label the pixels in the image with the real information (Jensen & Gorte, 2001). Through the classification of remotely sensed image, thematic maps such as the LULC can be obtained (Tso & Mather, 2001). There are two broad types of classification procedures; one is referred to as supervised classification, and the other one is unsupervised classification. These approaches are often combined into hybrid methodologies using more than one method (Richards & Jia, 2006).
Laliberte et al., (2004) generated a new concept called object oriented method, which allows the integration of a wide field of different object features such as spectral values, shape, and texture. Such classification techniques incorporate contextual and semantic information, image object attributes and relationship among different image objects. Numerous researchers have addressed the problem of accurately monitoring LULC change in wide applications with greater success (Chan et al., 2001). This is due to a wide variety of change detection techniques and algorithms, which have been developed over the past few decades.

According to Owojori and Xie, (2005), accuracy assessment is an essential and most crucial part of studying image classification and change detection in order to understand and estimate the changes accurately. It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis. There is no single and appropriate method for assessing the accuracy of change detection products.

Foody, (2002) demonstrated that the most common and popular method for accuracy assessment for LULC is the error matrix or confusion matrix method, which can be further used for change detection studies. The related assessment elements include overall accuracy, producer accuracy, user accuracy, and kappa coefficient. Previous studies provided the meanings and methods of calculation for these statistical elements for judging the accuracy (Congalton, 1991, Congalton & Green, 1999, Foody, 2002).

Based on these technical guidelines, researchers throughout the world have been exploiting this technology for various applications in terms of landuse classification. Wagner et al., (2013) assessed the impacts on landuse change on water resources of the Mula and Mutha river catchment. They identified an increase of urban area from 5.1% to 10.1% and cropland from 9.7% to 13.5% of the catchment area during the 20 year period.
Ansari et al., (2013) deciphered the effect of geology and geomorphology on landuse/land cover in Himalayan foothill. They identified and recognized landforms like, doon fan gravel terrace, doon fan gravel dissected hill, sub recent fan terrace, moderately dissected structural hill, piedmont dissected slope, river terrace, channel bar and river channel using supervised classification of aster false color composite images.

2.4 Reviews on soil erosion

Soil erosion is a complex land denudation process, in which surface soils are removed and deposited at a far-away place. It is considered as one form of soil degradation along with soil compaction, low organic matter, loss of soil structure, and poor internal drainage problems (Jain et al., 2001; Jianrong et al., 2008). Soil erosion is a major problem all around the world and has great influence on the societal, and environmental setup due to on-site and off-site reparation (Baba & Yusof, 2001; Pandey et al., 2007; Yuksel et al., 2008).

Frequent anthropogenic activities, such as construction, mining, and agricultural activities disturbs the land surfaces, which results in soil erosion. Narayana and Babu, (1983) inferred that, about 53% of the total land area in India is prone to erosion and about 5,334 million tonnes of soil are being detached annually due to various reasons. To overcome this problem, soil conservation measures have been adopted in which sustainable soil conservation method is more promising. This can be achieved only by comprehensive understanding of the extent, risk, and spatial distribution of soil erosion (Bewket & Teferi, 2009; Wang et al., 2009).

In this context, various models have been developed for the assessment of soil erosion. According to Bhattacharai and Dutta, (2007), the soil erosion models can be classified into two groups: (1) physically based models and (2) empirical models. Physically based models such as WEPP (Flanagan & Nearing, 1995), ANSWERS
(Beasley, 1989), and KINEROS (Woolhiser et al., 1990) explore erosion processes by combining individual components. Moreover, these models provide good information on spatio-temporal conditions of soil erosion. It is often difficult to simulate physically based models due to lack of required data for analysis (Bhattarai & Dutta, 2007).

On the other hand, empirical models such as Universal Soil Loss Equation (USLE) Wischmeier and Smith, (1965), the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975), and the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), are the most commonly used methods to predict soil erosion especially in watershed areas due to their minimal data requirements and ease of application (Lal, 2001; Bhattarai & Dutta, 2007; Zhang et al., 2009).

The Universal Soil Loss Equation (USLE) model was first suggested by Wischmeier and Smith, (1965) in order to calculate the amount of soil erosion in agricultural areas based on the concept of the separation and transport of particles by rainfall. The equation was modified in 1978. It is the most widely used and accepted empirical soil erosion model developed for sheet and rill erosion based on a large set of experimental data from agricultural plots.

Boggs et al., (2001) assessed soil erosion risk based on a simplified version of RUSLE using digital elevation model (DEM) data and soil mapping units. Wang et al., (2003) used a sample ground dataset, Thematic Mapper (TM) images, and DEM data to predict soil erosion loss through geostatistical methods. They showed that such methods have provided significantly better results than using traditional methods.

Renard et al., (1994) provide a detailed summary of the differences between USLE and RUSLE. Prominent modifications include corrections of the R factor, new equations based on the ratio of rill to inter-rill erosion that accommodate complex aspects of LS factor and the implementation of new sub-factors for calculating the C factor and the new
P factor (Renard et al., 1991). Notwithstanding these modifications, the RUSLE model has retained the same fundamental structure as the USLE (Renard et al., 1994).

Zhou et al., (2008) explored the relationship between soil loss and its influencing factors in a mountainous watershed in southwestern China, and found that C-factor and LS-factor of the USLE equation were the most important factors affecting soil loss distribution.

Moreover, research in the Upper Nam Wa watershed in Nan province of Thailand showed that most of the total soil loss occurred in shifting cultivation (69.9%) and scrub (18.3%), suggests that landuse is the key factor affecting spatial distribution of soil erosion (Krishna Bahadur, 2009).

Application of GIS is increasing progressively in soil erosion prediction. There are several examples for the integration of GIS with erosion models: De Roo et al., (1989) combined ANSWERS with GIS technology; Mitchell et al., (1993) linked AGNPS with GIS. The USLE is originally developed to predict long term average annual erosion. Julien and Frenette, (1987) studied the Chaudiere basin in Canada to examine the applicability of the USLE to a large area. They have used a correction factor to the large watershed to extend the applicability of the USLE.

Molnar and Julien, (1998) have compared soil erosion to different grid cell size. They concluded that large grid cell sizes under estimate soil losses because of the terrain slope effects. They suggest that a correction factor is needed to solve the under estimation of soil loss at a macro-scale. Lufafa et al., (2003) have evaluated different methods of USLE input parameter derivation and predicted the soil loss within a micro-catchment of the Lake Victoria Basin. In the terrain units, soil loss is highest within back slopes followed by the valleys. This study pointed that GIS based USLE approach has the ability to predict soil loss over large areas due to the interpolation capabilities.
Vijith et al., (2012) have used remote sensing and GIS-based soil erosion assessment techniques for a tropical mountainous watershed in Kerala. They assessed the influence of different landuse/land cover types and other terrain variables in the study area on the basis of probability of soil erosion and the rate of soil erosion in each pixel to derive suitable protection measures.

Demirci and Karaburun, (2012) estimated the rate of soil erosion using GIS based RUSLE technique in the Buyukcekmece Lake watershed, northwest Turkey. The study provided a reliable prediction of soil erosion rates and delineation of erosion-prone areas within the watershed and requires implementation of effective soil conservation measures to reduce soil erosion risk.

Bartsch et al., (2002) have used GIS techniques to interpolate RUSLE parameters for determining the soil erosion risk in sample plots Camp Williams, UT, USA. Wilson and Lorang, (2000) have reviewed the applications of GIS in estimating soil erosion. They have discussed the difficulty and limitations of previous research and concluded that GIS provided tremendous potential for improving soil erosion estimation.

RUSLE, which is the revised version of USLE not only provides an estimation of soil loss at the plot scale, but also presents the spatial distribution of soil erosion (Renard et al., 1991, 1997; Onyando et al., 2005). Simplicity of the model, which requires less data and time to run, and its convenience to be used together with GIS make RUSLE the most frequently used empirical soil erosion model worldwide (Fu et al., 2005; Youe-Qing et al., 2008). GIS and remote sensing (RS) are the tools which have been used effectively in cooperation with many different models, such as RUSLE, to predict soil loss. As Zhou and Wu, (2008) indicated in their study, GIS facilitates the model’s process by allowing the quantification of the impact of a single factor on the overall result. By dividing the area into small grid cells, GIS provides an in-depth analysis of individual factors such as
soil type, slope, and landuse, all of which contribute to soil erosion (Bhattarai & Dutta, 2007). Many studies used a combination of RUSLE and GIS to predict soil erosion at a watershed level (Youe-Qing et al., 2008; Kouli et al., 2009; Terranova et al., 2009).

2.5 Reviews on impact of landuse change on water quality

Landscape features such as terrain condition, underlain geology, landuse/land cover, hydrology and climatic conditions affect the whole aquatic ecosystem (Tong & Chen, 2002). Landuse and land cover is one of the most significant features governing the water quality of a basin (Griffith et al., 2002) and its management practices influence the water budget, water chemistry and biodiversity of aquatic organisms in receiving waters (Environment Canada, 2001). Poor management practice often leads to water pollution, in which agriculture and municipal waste water effluent represent two different types of pollution. Municipal sewage is considered to be point source pollution, which originate from a single source and are relatively simple to monitor because the source can be readily identified. On the other hand, pollution from agriculture is often considered to be non-point source as they diffuse across the landscape. They are triggered by seasonal agricultural activity or irregular events such as heavy rainfall. Non-point sources of pollution often emanate from land and are transported through overland, underground, and through the atmosphere to receiving waters (Carpenter et al., 1998) and therefore difficult to measure and regulate. The most common pollutants arising from point and non-point sources are nutrients, particularly nitrogen and phosphorus, sediment, pesticides, pathogens, and endocrine disrupting substances (Chambers et al., 2000). These substances have great potential to make the water unfit for humans use and can destroy the aquatic habitat.

Understanding the relationships between catchment characteristics and river water chemistry provides a base for determining how future changes in landuse and climate will
impact on river water quality and functioning (Robson & Neal, 1997; Jarvie et al., 2002). Therefore, it is important to determine the processes that regulate stream water chemistry in landscapes under increasing pressure from human population, whether from urbanization or more intensive food production.

The effect of land use on nutrient concentrations in rivers has been studied by several researchers (Osborne & Wiley, 1988; Wahl et al., 1997; Tufford et al., 1998). For example, studies conducted by Eyre and Pepperell, (1999) have showed that elevated levels of nutrients are associated with leaching of excess fertilizer that has been applied in cane land of Rous River catchment in northern NSW Australia. Cooper, (1993) pointed out that eutrophication is one of the serious issues in river degradation caused by high levels of nitrogen and phosphorus in the surface water bodies. Thus, degrading the water quality by reducing the dissolved oxygen level.

Algal blooms in water bodies have been reported as a result of diffuse agricultural sources of phosphorus (Correll, 1998; Dils et al., 1999; Daniel et al., 1998) and increased levels of nitrogen (Rabalais et al., 2002) which in turn cause hypoxia. Heavy nutrient flux in rivers can enhance the algal growth and affects the river health and hydrological settings of a basin.

Several factors determine the fate of nutrient concentration and transport in a river system such as geography (Rohm et al., 2002), land cover (Lovett et al., 2000; Lewis & Likens, 2000; Binkley et al., 2004) and rock type (Holloway & Dahlgren, 1999). Nutrients, for instance phosphorus are transported in various forms such as dissolved, sediment attached and particulate (Nash & Murdoch, 1997; Stevens et al., 1999). Ierodiaconou et al., (2005) studied the land use change on nutrient exports in southwest Victoria using an export coefficient model, remote sensing and GIS technique. The major reason for spatio-temporal variations in water quality of a tropical river is associated with
landuse changes and construction of dams across the rivers (Raj & Azeez, 2009) resulting in water stagnation and sedimentation. Sediments not only affect the habitat of aquatic organisms (Jowett & Boustead, 2001; Ellis et al., 2002) but also reduce the aquatic productivity (Ryan 1991).

Holloway et al., (1998) have reported that metavolcanic and metasedimentary rocks are the source of higher nitrate concentrations in lower reaches in the Mokelumme River watershed in Central Sierra Nevada of California. Similarly, Wooten et al., (1999) found that the rivers draining though limestone bedrock has higher nitrate concentration than those draining through sandstone bedrock.

Meynendoncks et al., (2006) reported that there is a positive correlation between river nitrate concentrations and effluents coming from the wastewater treatment plants and agricultural land whereas, phosphorus concentrations were influenced by industrial waste. According to Brett et al., (2005), strong correlation is noticed between land cover type and phosphorus concentrations in the streams along a forest to urban gradient. Moreover, agricultural and urban landuse can enhance the nutrient content in adjoining river water (Soranno et al., 1996; Doyle, 2005).

Sabater et al., (1990) showed a strong correlation between different landuse variables and the nutrient content of the river Ter, Spain. These site-specific studies show the existence of a close correlation between water quality and catchment characteristics such as landuse, geology and soil type. Forest has a significant control on nutrient concentrations in a river. Van-Miegroet et al., (1992) described that ammonium produced by red alder trees in summer was nitrified and stored in the forest soils and then washed out during winter season through the streams when the biological uptake of inorganic nitrogen is at minimum levels. A study conducted in a mixed conifer forests in Southern California showed that elevated nitrate concentrations in rivers were caused by nitrogen
saturation where atmospheric deposition reached 20 to 25 kg N/ha/year or greater (Fenn et al., 1996; Kiefer & Fenn, 1997).

Spalding and Exner, (1993) assessed the escalating rate of nitrate concentrations in surface and groundwater all over the world and the sources of these nutrients are derived from chemical fertilizer and animal manure. Nitrate is susceptible to leaching to waterways because of the small size and high mobility of the anion (Keeney, 1986).

The application of fertilizers on farm lands exceed the crop uptake rate, which eventually results in polluted groundwater and surface water through various pathways thus deteriorating the water quality (Meybeck & Helmer, 1992; Harper et al., 1992). Moreover, a positive correlation between the quantity of fertilizers used in the crop land and the nutrient load in the river water is reported by McColl, (1978).

Sims et al., (1998) inferred that soil types also involve in nutrient retention in cultivated lands and intensive application of manures can increase the phosphorus movement to river systems. During heavy rainfall, nutrients particularly phosphorus can be transported through runoff in a medium to fine textured soil adjacent to a river system (Pote et al., 1999) whereas in a course textured soil, the nutrients have a tendency to leach into the groundwater and move laterally through sub-surface flow (Novak et al., 2000).

Similarly, other researchers have reported that the use of nitrogenous fertilizer and the type of landuse were related to the amount of nitrogen exported to the adjacent river (Little et al., 2003; Buck et al., 2004; Donner et al., 2004; Lattin et al., 2004; Woli et al., 2004). Riparian vegetation along a river system can play a significant role in reducing the nutrient load and also influence the in-stream biological functions (Cey et al., 1998; Cummins, 1993). Basynat et al., (1999) reported that riparian landuse was more significant in determining stream nutrient concentrations than landuse over the whole river basin. Well maintained riparian vegetation can act as a filter to minimize the rate of
soil and nutrient movement into the river system. Thus preventing the in-stream habitat deterioration by avoiding siltation and moderating temperature variation of a river (Price & Lovett, 2002; Broadmeadow et al., 2010). Wilcock et al., (1998) stated that rivers with poor riparian vegetation cover is expected to have lower dissolved oxygen concentration as oxygen solubility decreases with increase in temperature.

Studies conducted by Whiles et al., (2000) revealed that stream water chemistry and invertebrate health and diversity are positively related to riparian landuse in agricultural basin of north-eastern Nebraska, United State of America. Similarly, Chang, (2008) found that landuse, topographic and soil factors at 100 meter riparian buffer has more influence on variation of total nitrogen and total phosphorus than the whole catchment landuse in the Han River of South Korea.

2.6 Reviews on GIS and statistical methods in river basin management

To identify how landuse characteristics are associated with the spatial and seasonal variations of water quality, many researchers have used statistical methods combined with GIS and remote sensing (Kay et al., 2005; Park & Stenstrom, 2006; Plummer & Long, 2007). It is necessary to acquire aerial photography or satellite imagery to quantify the spatial landuse data in a watershed. These remotely sensed datasets taken at different time periods provide valuable information on physical characteristics of the landscape, such as landuse and vegetation cover (Borrough & McDonnel, 1998). Similarly, digital elevation models (DEM) have been widely used to delineate stream orders, geomorphology, catchment boundaries, and sub-catchments for each water monitoring station (Moore et al., 1991). These techniques help to identify the basin features and assist to understand the relationship between landuse and water quality (Tong & Chen, 2002). GIS not only can integrate and analyse spatial and temporal data to quantify the landuse changes, but it can also help to assess the landscape characteristic very quickly and relate these to the
adjacent river water quality parameters (Chang, 2008). Using GIS, researchers can evaluate the landscape characteristics and landuse changes with respect to water quality patterns.

Chang and Carlson, (2005) investigated chloride, total organic carbon and lead concentrations in 10 small central Pennsylvania streams using GIS-derived land cover characteristics and road density. Ahearn et al., (2005) have examined the relationship between land cover and total suspended solids and nitrate-nitrogen loading in Sierra Nevada streams in California, United States of America.

Chang, (2008) used spatial data and GIS software to study the spatial and temporal patterns of water quality using spatial autocorrelation techniques in the Han River in South Korea. Several studies have applied statistical models combined with GIS and remotely sensed data to know how watersheds are linked with the spatial variation of water quality in the river. Wang and Yin, (1997) used GIS to observe possible links between spatial landuse data and water quality data in the Great Miami River, United States of America.

Ravichandran et al., (1996) have used multivariate statistical technique like principle component analysis (PCA) and hierarchical cluster analysis to define ecoregions in the Tamiraparani river basin. The main goal of the multivariate statistical technique is to extract useful information and provide an easier visualization of the relations among objects and variables determined in large or complex datasets (Pardo et al., 2004). This allows a better understanding of contamination sources and environmental processes (Boruvka et al., 2005). Multivariate statistical techniques has been widely used in groundwater studies for characterizing the hydrogeochemistry (Suk & Lee, 1999; Suvedha et al., 2009; Yidana & Yidana, 2010). Statistical techniques, for example cluster analysis, can provide a powerful tool for analyzing hydrogeochemical data. This method
can group distinct populations (hydro-chemical groups) that are significant in the
geologic, as well as statistical point of view. Cluster analysis was successfully used
(Alther, 1979; Williams, 1982; Farnham et al., 2000) and applied to classify water-
chemistry data (Güler et al., 2002).

Shrestha and Kazama, (2007) applied statistical techniques like cluster analysis (CA),
principal component analysis (PCA), factor analysis (FA) and discriminant analysis (DA)
to evaluate water quality of Fuji river basin in Japan. In a similar study, Singh et al.
(2005) applied CA, FA, PCA, and DA to analyze water quality variations in Gomti river
in India. Bengraine and Marhaba, (2003) used principal component analysis (PCA)
applied on water quality data of Passaic river in New Jersey. The multivariate statistical
technique of PCA helped in finding the factors responsible for spatial and temporal
variations of water quality.

The water quality of Pisuerga river was analyzed by Vega et al., (1998). The
experimental data was interpreted using box plots, ANOVA, display methods (principal
component analysis) and unsupervised pattern recognition (cluster analysis) for
discriminating the sources of variation in water quality. Spatial and temporal variations in
the water quality of Alberche River, Spain were examined by Perona et al., (1999) during
two consecutive years. Principal component analysis is used to analyze the environmental
factors associated with the physico-chemical variability.

Geostatistical techniques such as variogram analysis and kriging are widely applied in
groundwater research (Bonham-Carter, 1996; Isaaks & Srivastava, 1992). These
techniques allow the computation of regional patterns and contour plots under
consideration of the spatial distribution of the input data.

Priya and Arulraj, (2011) used correlation-regression model for evaluating the
physicochemical parameters of groundwater in Coimbatore city and successfully
predicted the inter-relationship between Ca, Mg and TH. Daraigan et al., (2011) applied a linear regression model for drinking water quality in AlMukalla City, Hadhramout, Yemen.

The temporal assessment of data is more complicated and usually requires statistical analyses on long-term records of groundwater quality data. For example, a study conducted by Chang, (2008) presents spatial analysis results of water quality trends in Han river basin, South Korea. The non-parametric seasonal Mann–Kendall test is used for eight water quality parameters to determine the significance of trends for each parameter. However, in the absence of long-term data, trend testing procedures like the Mann–Kendall test are not suitable and different tests must be used.

Kannel et al., (2008) examined the spatial and temporal variations and factors influencing the management of groundwater along a section of the Bagmati river corridor in the Kathmandu Valley (Nepal). Only two sets of data existed in this study; therefore, the two-tailed $t$ test was implemented to examine the difference of groundwater quality from pre monsoon to post monsoon seasons and subsequently from rural areas to urban areas. The approach taken to assess the temporal change in water quality ultimately depends on the availability of data and the time scale of the assessment, i.e., seasonal fluctuation of water quality against long-term trends.

Backman et al., (1998) have used an index for evaluating the degree of groundwater contamination and verified its applicability in South-Western Finland and Central Slovakia. Soltan, (1999) has used WQI to indicate the quality of groundwater from ten wells located near the Dakhla Oasis in the Western Egypt. Many studies (Kim, 2009; Babiker et al., 2007; Rivard et al., 2008) have been done on a regional scale with respect to groundwater quality and quantity. Ramakrishnaiah et al., (2009) used water quality index to assess the groundwater quality of Tumkur taluk, Karnataka and the study reveals
that the groundwater of the area needs some degree of treatment before consumption. Vasanthavigar et al., (2010) assessed the water quality for human consumption using WQI method for the pre and post monsoon seasons in Thirumanimuttar river basin. They identified that the leaching of ions, over-exploitation of groundwater, direct discharge of effluents, and agrochemicals are responsible for the poor quality of water in pre monsoon season.

So far, significant studies on the Tamiraparani river basin have been conducted by few researchers in south India. But, most of the research work carried out in this basin is related to biological water quality and related disciplines (Murugesan et al., 1994; 2000; 2002; 2004; Mophin Kani & Murugesan, 2010; 2011). Britto and Baskaran, (2010) studied the impact of industrial effluents and sewage on river Tamiraparani and concluded that the major canals associated with the main river are bacteriologically contaminated due to sewage dumping.

Balasubramanian and Sastri, (1987) studied the groundwater quality of Tamiraparani river basin and Subramani, (2005) assessed the hydrogeology and hydrochemistry of Tamiraparani basin using groundwater modeling techniques. Ravichandran, (2003) reported the hydrological influences on the water quality trends in Tamiraparani basin. He pointed out that the changes induced in river flow by the addition of a stabilizing reservoir, the influence of seasonal and spatial pattern of monsoon rainfall across the river basin and the increased agriculture appears to be causative factors for the water quality trends seen in the Tamiraparani river system. James, (2000) studied the environmental biogeochemistry of Tamiraparani river basin. He pointed out that the rock water interaction and groundwater inflow influences the water chemistry. Moreover, a fivefold increase in trace metals (As, Cr, Cu, Ni, Se and Zn) was observed in the downstream region, which is derived mainly from anthropogenic sources.
Kumarasamy, (2010) has carried out an environmental impact assessment of Tamiraparani river basin and evaluated the organochlorine pesticide level along the main channel. Among the OCPs, the levels of dichloro-diphenyl-trichloro-ethanes (DDTs), aldrin, dieldrin, cis-chlordane, transchlordane, and mirex were dominant in the sediments. The dominant OCPs in water samples are heptachlor,o,p′-DDE, dieldrin, o,p′-DDD, and mirex, which show different source of contamination pattern among sampling seasons. Also, James and Ramesh, (1999) assessed the organochlorine pesticide levels in water and sediments of Tamiraparani river basin. The sources of these pesticides are from agricultural and municipal outfalls.

Hema and Muthalagi, (2009) have assessed the pollution load in the Tamriaparani river through mass balance approach. The results indicate that non-point sources are the major contributors of pollution and they are derived from agricultural practices, soil erosion, and dissolution of soil minerals.

Joseph, (2011) has studied the petrography, chemistry and evolution of soils in Tamiraparani basin and compared with Neyyar basin in Kerala. The difference in weathering pattern and the role of contrasting climate in developing the differential weathering scenarios has been established.

Moreover, geochemistry of Tamiraparani estuarine sediments has been extensively studied by Vetha Roy, (2002) and the result shows that the sediments have been contaminated with Zn, Cd, and Hg in terms of enrichment factor. The sources of these metals are derived from anthropogenic activities and fluvial origin. The spatial distribution of trace elements in this estuary has been evaluated by Magesh et al., (2011a) using GIS techniques. The Igeo spatial map indicates that the Cd content in the sediments is well distributed in the southern part of the estuary. Also, the trace element concentration in sediments of Tamirabarani river in relationship with physico-chemical
characteristics and its application using GIS has been studied by Chandrasekaran et al., (2013).

Ramesh et al., (2002) have reported the sediment accumulation rate in Tamiraparani river and estuary. They found that the sedimentation rates were higher in the midstream and downstream regions. The higher rate in these regions is possibly due to the effect of damming. Further a sharp increase in the sedimentation rates in the estuarine region may also indicate the rapid deposition of sediments due to flocculation, occurring at the freshwater-seawater transition.

Suresh Gandhi et al., (2008) have studied the sediment characteristics and heavy mineral distribution in Tamiraparani estuary and off Tuticorin through SEM studies. The assemblage of heavy minerals is restricted to the dominance of few selective minerals like garnet (colourless), garnet (pink), zircon, rutile, chlorite, etc. They have also noticed that in pre monsoon, the deposited sediment were transported and shifted due to long shore current action. But, in the post monsoon period the sediments deposited due to the multi-source like riverine and marine influence.

A careful cursory of the literature reveals that there is no detailed studies in this region, which describes the effect of landuse on water quality. Therefore, the present work has been culminated to address the impact of landuse change on water quality of Tamiraparani sub-basin, Tamil Nadu.