

WATER QUALITY STATUS OF SHARAVATHI RIVER BASIN, WESTERN GHATS

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CONTENT

Abstract

1. Introduction

2. Objectives

3. Study Area

4. Materials and Methods

4.1 Water Quality Studies

4.2 Hydrological Investigations

4.3 Catchment Investigations

4.3.1 GIS and Remote sensing

4.3.2 Vegetation analysis

4.3.3 Soil Analysis

5. Results and Discussion

6. Conclusion

Figures

Figure 1: Stream Drainage Pattern.

Figure 2: Ordering of Streams

Figure 3: Sharavathi River Basin.

Figure 4: Sub Basins in Upstream River Sharavathi.

Figure 5: Transect cum quadrat method of Vegetation analysis.

Figure 6: Land use analysis – Upstream of Sharavathi river basin

Figure 7: Variations of pH between the Sub basins

Figure 8: Variations of Conductivity between the Tributaries

Figure 9: Variations of TDS between the Tributaries

Figure 10: Variation of Sodium between the Tributaries

Figure 11: Variation of Potassium between the Tributaries

Figure 12: Percentage Forest in the Catchment of the Tributaries

Figure 13: Variation of Stream flow between the Tributaries

Figure 14: Annual Rainfall Across the sub basins of Sharavathi River Basin.

Figure 15: Variation of Stream flow in Nandhiholé sub basin

Figure 16: Variation of Stream flow in Nagodiholé sub basin.

Figure 17: Variation of Stream flow in Yenneholé sub basin

Figure 18: Correlation between Endemism and Stream flow

Figure 19: Correlation between Evergreenness and Stream flow

Figure 20: Correlation between Basal Area and Stream flow

Figure 21: Correlation between Trees/ha and Stream flow

Figure 22: pH-Nandhihole & Figure 23: pH-Nagodihole

Figure 24: pH-Yennehole & Figure 25: Ec-Nagodihole

Figure 26: Ec-Nandhihole & Figure 27: Ec-Yennehole

Figure 28: Tds-Nsandhihole & Figure 29: Tds-Nagodihole

Figure 30: Tds-Yennehole & Figure 31: Sodium-Nandhihole

Figure 32: Sodium-Nagodihole & Figure 33: Sodium-Yennehole

Figure 34: Potassium-Nagodihole & Figure 35: Potassium-Nandhihole

Figure 36: Potassium-YenneholeS

Tables

Table 1: Methodology for water Quality Analysis

Table 2: Palmer's Index.

Table: 3 Methods for analysis of soil

Table 4: Land use Pattern Among of Catchment Area of Eight Tributaries of River Sharavathi (in km²)

Table 5: Land use (%) in the Catchment of Eight Tributary

Table 6: Variation in Physico-chemical parameters in Tributaries of River Sharavathi.

Table 7: Physico-chemical characteristics of water from Nandhiholé sub basin

Table 8: Physico-chemical characteristics of water from Yenneholé sub basin

Table 9: Physico-chemical characteristics of water from Nagodiholé sub basin

Table 10: Physico-chemical characteristics of soil from Nandiholé (NA), Nagodiholé (NG) and Yenneholé (YE) sub basins.

7. References

8. Acknowledgement

Appendix -1

Appendix -2

PDF

ABSTRACT

Aquatic ecosystem is one of the most productive ecosystems providing many critical services to humans, such as plants (both macrophytes and algae) carry out photosynthesis and produce the oxygen, bacteria process the organic waste products and maintain good water quality, riparian vegetation mitigates floods and provides more stable river and spring flows, more reliable flow regimes can be utilised for food production, transport, water supply or to support terrestrial ecosystems and wildlife. Healthy ecosystems ensure maintenance of biodiversity and hence resilience to the pressures of utilization. The holistic approaches in planning involving all components are required to maintain the health as well as to ensure the sustainability. This requires timely and accurate data pertaining to the quality and quantity. This necessitates inventorying, and regular mapping and monitoring involving hydrology, and physico-chemical and biological properties.

The objective of this endeavor was to investigate the ecological status of the Sharavathi River Basin, Western Ghats through hydrology, land use, soil and water quality assessments. The micro-level assessment included the vegetation analysis (at sub-basin levels), water quality and soil analysis, stream discharge analysis of selected twelve streams in three sub-basins Nandiholé, Nagodiholé and Yenneholé of River Sharavathi. The physico-chemical analysis of water shows that the tributaries Nandiholé, Haridravathi and Mavinholé with high values of pH, alkalinity, electrical conductivity, total dissolved solids, sodium, potassium, Palmer's index, coliform bacteria, etc. is polluted while compared with other tributaries This is mainly due to the agricultural activities and the resultant run-off to these sub-basins.

The rainfall data of twenty years show significant variation among the sub basins. The stream flow results reveal that that the tributaries from the western side discharge more water than the tributaries from the eastern side. Also, the streams on western sides are perennial compared to the eastern side (seasonal streams). The land use and land cover analyses show the linkage between land use pattern and hydrology in the sub-basin. The catchment area with good evergreen to semi-evergreen vegetation cover shows a high

stream discharge while the sub-basin with plantation and agricultural activities shows seasonal streams with low stream discharges.

This indicates that the land-use pattern in the catchment area plays a major role in the health of the aquatic ecosystem, which is evident from the water and soil quality analyses. The occurrences of perennial streams highlight a vital relationship between the ecology and hydrology. This result could be a pointer to the decision-makers considering a severe water stress faced in various parts of the Country. Hence, forest management activities should incorporate multifarious objectives of improving water production, both by quantity and quality through an appropriate land use planning.

1. INTRODUCTION

In many countries, legislation mandates assessment of the water chemistry, biota, and physical environment of rivers, many of which have been highly impacted by human activities. For example, the objective of the Water (Prevention and Control of Pollution) Act, 1974 is “the prevention of control of water pollution and the maintaining or restoring of wholesomeness of water,” Clean Water Act of the United States is “to restore and maintain the chemical, physical, and biological integrity of the nations' surface waters.” Similarly, the Water Framework Directive of the European Union includes consideration of: (1) biological elements such aquatic flora, benthic invertebrates and fish; (2) hydro-morphological elements such as water flow, groundwater dynamics, river depth, width and continuity; and (3) chemical and physiochemical elements such as thermal and oxygenation conditions, salinity, acidification, nutrients, and specific pollutants ([Stalzer and Bloch, 2000](#)). Addressing such diverse components poses a serious challenge for monitoring riverine systems. Landscape ecology emphasizes the interaction between spatial pattern and ecological process ([Turner, 1989](#); [Turner et al., 2001](#)) and has conceptual and technical tools relevant to the monitoring of rivers and their associated catchments. Simple landscape metrics describing the amount of human altered habitats can be useful indicators of water chemistry, biotic and hydrologic variables, which in turn save the aquatic ecosystem.

Aquatic ecosystem is one of the most productive ecosystems in the world. In spite of the enormous volume of the water in the planet, only a small portion of it is available for our use. 97 % of the total water is present in oceans and sea as saline water, which is not useful; while fresh water makes up only 2.6 % and 4 / 5 of that is immobilized as ice and thus equally useless. Fresh water aquatic ecosystems include streams, rivers, lakes, ponds, and ground water. The large proportion of the earth's biodiversity resides in aquatic environments ([McAllister et al , 1997](#); [Groombridge and Jenkins 1998](#)). Numerous plants and animals, ranging from microscopic algae to large plant, from protozoans to mammals, a variety of morphological, anatomical, and physiological adaptations allow them to survive and grow in water ([Gopal and Chauhan, 2001](#)).

Aquatic ecosystem provide many critical services to humans, such as plants (both macrophytes and algae) carry out photosynthesis and produce the oxygen and bacteria process the organic waste products and maintain good water quality. Riparian vegetation mitigates floods and provides more stable river and spring flows, more reliable flow

regimes can be utilised for food production, transport, water supply or to support terrestrial ecosystems and wildlife. Healthy ecosystems ensure maintenance of biodiversity and hence resilience to the pressures of utilization. Fresh water environments are divided into two major categories, lotic (*lotus* = washed or running water), and lentic (*lenis* = calm or standing water) habitats based on the currents and ratio of the surface area. Lotic habitats are those existing in relatively fast running streams, springs, rivers and brooks. Lakes, ponds, swamps, etc represent the lentic habitats ([Diwan and Arora, 1995](#)). The holistic approaches in planning involving all components are required to ensure the sustainability. This requires timely and accurate data pertaining to the quality and quantity. This necessitates inventorying, and regular mapping and monitoring of the drainage basin.

Aquatic bodies can be fully assessed by three major components, hydrology, physico-chemical, and biology. A complete assessment of water quality is based on appropriate monitoring of these components.

Aquatic quality assessment is the overall process of evaluation of the physical, chemical and biological nature of the water in relation to natural quality, human effects and intended uses, particularly which may affect human health and health of the aquatic ecosystem. The main theme of the aquatic quality assessment is to:

- define the status of water quality,
- identify the trends in water quality,
- define the causes of observed condition and trends,
- identify the types of water quality problems that occur in specific geographical areas, and
- provide the accumulated information and assessments in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions

All freshwater bodies are inter-connected, from the atmosphere to the sea, via the hydrological cycle. Thus water constitutes a continuum, with different stages ranging from rainwater to marine waters. The hydrodynamic characteristics of each type of water body are highly dependent on the size of the water body and on the climatic conditions in the drainage basin.

Hydrology: Water in the catchment, its occurrence, distribution and circulation, its physical and chemical properties, their effect on the environment and on life of all the forms is well understood through proper understanding of the hydrologic process in the catchment. The direction of movement of the water is fundamental property of lotic ecosystem. Dissipation of energy from moving masses of water affects the morphology of streams, sedimentation patterns, water chemistry, and biology of organisms inhabiting them. The continual down gradient movement of water, dissolved substances, and suspended particles in streams and rivers is derived primarily from the land area draining into a given stream channel. The hydrological, chemical, and biological characteristics of

a stream or river reflect the climate, geology, and vegetation cover of the drainage basin ([Hynes, 1970](#); [Oglesby *et al.*, 1972](#); [Beaumont, 1975](#); [Likens *et al.*, 1977](#)).

Drainage basin (drainage basin is equivalent term to watershed, catchment) is the area drained by tributary streams that coalesce into a main channel. The line, which divides the surface runoff between two adjacent river basins, is called the topographic water divide, or the watershed divide. The divide follows the ridgeline around the basin crossing the stream only at the outlet point. It marks the highest points between the basins, but isolated peaks within a basin may reach higher elevations than any point on the divide. The combined effects of climate and geology on the catchment topography yield an erosion pattern, which is characterized by a network of streams. Some of the frequently observed stream patterns are,

- i. Dentric: When a region is homogenous offering no variation in the resistance to the flow of water, the resulting streams run in all directions without definite preference to any one particular region.
- ii. Trellis: The trellis drainage pattern is develops when the underlying rock is strongly folded or sharply dipping. The longer streams will have preference to one particular orientation and the other tributaries will have an orientation and the tributaries will have an orientation at right angles to this.
- iii. Radial: The drainage pattern from dome Mountains and volcanoes is of radial type where the streams emanate from a central focus and flow radially outward.
- iv. Parallel and Sub parallel: The internal geological structure of the land, sometimes the parallel and sub parallel patterns are formed. The most of the streams run in the same direction is the main characteristic feature.
- v. Annular: The streams, which form in the weaker strata of the dome mountain, indicate approximately circular or annular pattern. The annular pattern may be treated as a special form of trellis pattern.
- vi. Rectangular: A region consisting of many rectangular joints and faults may produce a rectangular drainage pattern with streams meeting at the right angle.
- vii. Pinnate: In pinnate stream pattern, all the main streams run in one direction with the tributaries joining them at an oblique angle.

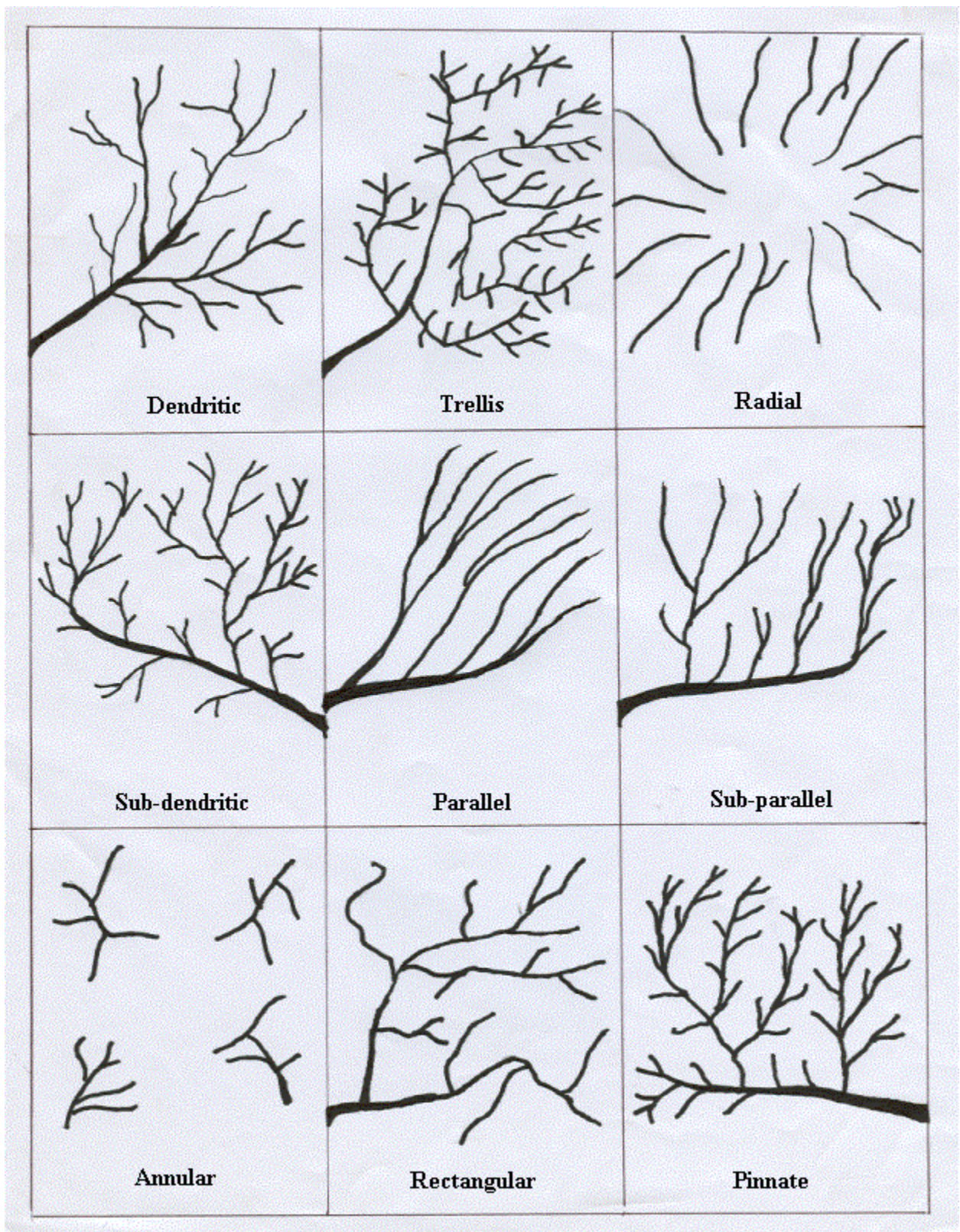


Figure 1: Stream Drainage Pattern.

The Horton Strahler method ([Horton, 1945](#); and [Strahler, 1952](#)) is widely used among several methods used for ordering the tributary streams in a drainage network (reviewed by [Gregory and Walling, 1973](#); [Gordon et al ., 1992](#)). The smallest permanent streams are designated as the first order and the confluences of two first order streams give rise to second order stream and so on. The order of trunk stream is not altered by the addition of lower order. The order of the stream will increase only by the addition of streams of same order ([Wetzel, 1991](#)).

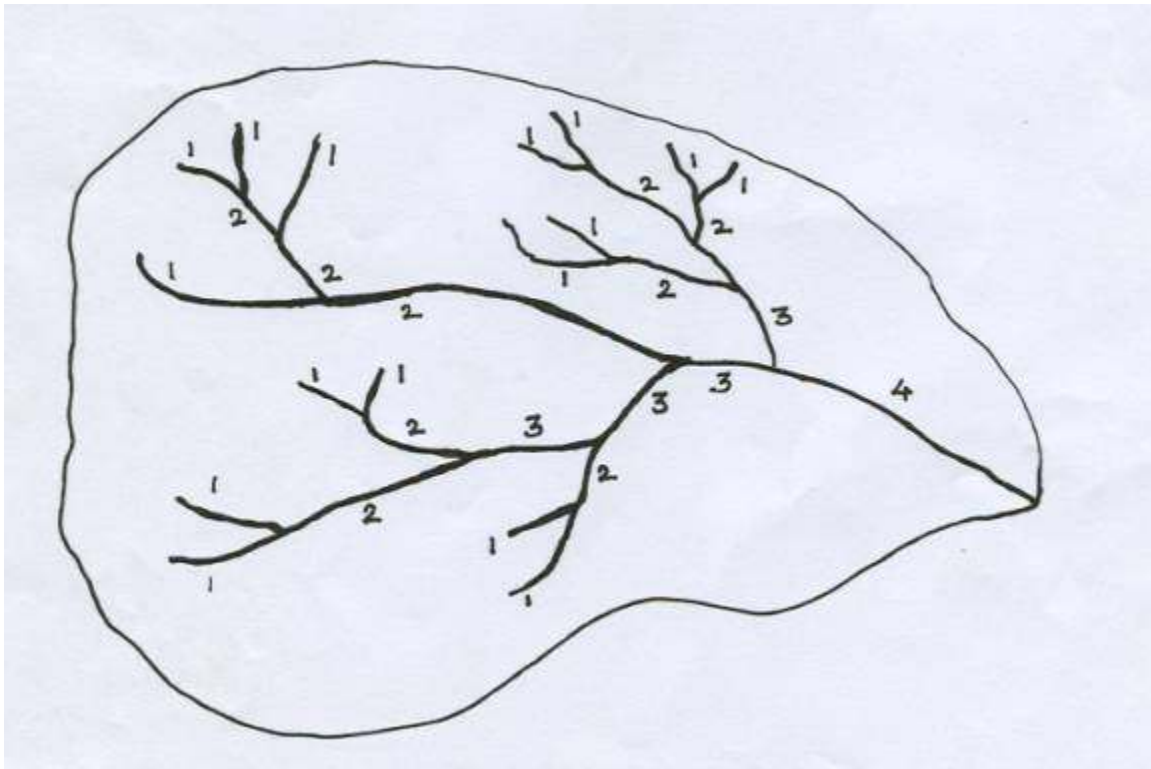


Figure 2: Ordering of Streams

The influence of the catchment area in the stream flow is very important. The important features that affect the stream flow are physiography of watershed, soil and geology, land use and vegetation cover.

The physiography of the watershed includes size, shape, land slope, drainage density and drainage pattern of the watershed. The size of the watershed is an important parameter in determining the peak rate of runoff. Long and narrow watersheds are likely to have longer times of concentration resulting in lower runoff rates than more square- shaped watersheds of the same size which have a number of tributaries discharging into the main channel near one point. The time and concentration also affects the amount of water, which will infiltrate into the soil in the watershed. The speed and extent of runoff water depend on the slope of the land. The drainage density affects runoff pattern, in that a high drainage density drains runoff water rapidly, decreases the lag-time and increases the peak of hydrograph, it depends on length of streams and catchment area. Drainage pattern

refers to the design of stream course and its tributaries and the slope of land, lithology and structure mainly influences it.

The soil and the geology of the watershed determine the amount of water infiltration. When the water comes in contact with sloping land in quantity exceeding immediate surface evaporation, part or all of it normally enters into soil. If the amount exceeds the immediate intake capacity of the soil, the excess flows along the surface as runoff. The proportion of the total precipitation that is finally disposed of in one or more of these forms (runoff, evaporation, transpiration, percolation, absorption) is greatly affected by the quantity and intensity of the rainfall, by the soil type, slope, type as well as density of vegetation cover, surface roughness, and such artificial barriers to off flowage as contour ridges, terraces, and water traps etc. In addition to the surface effects of vegetation in restraining runoff and increasing infiltration, other benefits from underground effects, such as increased organic supply and channels opened by ramifying root penetration. The quantity of organic matter contained in soils is important from many standpoints. The organic fraction of soil has a greater capacity, proportionately, for absorbing and storing water than mineral fraction. The infiltration capacity depends on the type of the soil, Sandy loam soil having more infiltration capacity than clay loam soil, because of high porosity and permeability in sandy loam ([Bennett, 2001](#)). The land in the watershed is used for several purposes like agriculture, roads, etc. Land use affects the rates of runoff, infiltration, water quality and vegetation of the watershed ([Tideman, 1996](#)). The quality and quantity of vegetation cover in the watershed determines the runoff, infiltration, erosion and evapotranspiration rates.

The water quality assessment is carried out by physical, chemical and biological investigations. Each fresh water body has an individual pattern of physical and chemical characteristics, which are largely determined by the climatic, geomorphological and geochemical conditions prevailing in the drainage basin. If the surface waters were totally unaffected by human activities, up to 90-99 % of global fresh waters, depending on the variable of interest, would have natural chemical concentrations suitable for aquatic life and most human uses. Natural events and anthropogenic influences can affect the aquatic environment in many ways, like synthetic substances may get added to water, the hydrological regime may be altered or physical or chemical nature of the water may be altered.

Most of the organisms living in a water bodies are sensitive to any changes in their environment. The response of organisms towards changes varies from inhibition of enzyme system to death of the organisms. Once the responses of particular aquatic organisms to any given changes have been identified, they may be used to determine the quality of water with respect to its suitability for aquatic life. The two main approaches used in biological assessment are estimation of quality by community structure or by the indicator organisms.

The vegetation studies reveal the nature of the land use in the catchment area. The endemics are species with restricted range ([WCMC, 1992](#)). A taxon is considered endemic, if confined to a particular area through historical, ecological or physiological

reasons. The quantitative evergreens of the sampling site show the nature of the forest type of the catchment.

GIS: The computer based geographical information system (GIS) is a tool that allows spatial and temporal analysis of all types of data ([Marble, 1987](#); [Walsh, 1987](#)). Since GIS are capable of combining large volumes of spatial data with attribute information from a variety of sources, it is a useful tool for many aspects of water quality investigations. They can be used to identify and to determine the spatial extent and cause of water quality problems, such as the effects of land-use practices on adjacent water bodies. They can also:

- Help to determine location, spatial distribution and area affected by point source and non-point source pollution,
- Be used to correlate land cover and topographical data with a variety of environmental variables such as run-off, drainage and drainage basin size.
- Be used for assessing the combined effects of various anthropogenic (e.g. land use) and natural (e.g. bedrock, precipitation) factors on water quality.

The two basic types of geographic data structures used in most GIS are raster and vector. The raster data structure is analogous to a grid placed over an image. This structure allows for the efficient manipulation and analysis of data, and preferred for overlay operations. Geographic features such as rivers, roads and boundaries are represented as vectors.

Ecological investigation is a combination of techniques, which enables data to be collected, relatively cheaply, on the life support capacities of large areas of land. The data concern plants, animals, earth components and people. The ecological investigations are mainly carried out in two ways,

- On the ground, either from fixed station or by mobile team of observer.
 - From space, using information and visual images supplied by orbiting satellites.
- Ecological investigation therefore begins with a survey of the habitats involved. Though vegetation survey is an important constituent of habitat monitoring, much more also is involved like the growth of vegetation, and the species mix most likely to survive, which depends on such factors as soil type and depth, water bodies, the nature and efficiency of natural drainage systems, faunal population, climatic factors such as rainfall, wind, and insolation, and the type of land-form involved like steep slope, broad valley, rocky outcrops, etc.

For long-term planning and management of water resources, future change of the pattern of land use, water demand and water availability should be analysed well in advance. Understanding how a water resources system responds to changing trends and variability requires knowledge of how it is affected by those conditions today and how it might respond in the future if those conditions change ([UNEP, 2001](#)).

Forests, occupying more than a quarter of the world's land area, have been degraded at unprecedented rates during the last century by farmers, ranchers, logging and mining

companies, and fuel wood collectors. Population growth and falling labour demand in many areas have released a huge flood of migrants seeking new livelihoods on forest frontiers. Transport infrastructure and control of diseases made such areas attractive. Also, these settlements have often been encouraged by governments, occasionally with support of the international development agencies. One reason for the high rate of over-exploitation is that too many functions of tropical forests are still undervalued by those responsible for their management. Unclear ownership rights and unstable legislation provide additional disincentives for their sustainable use.

Deforestation, understood as the net conversion from forest to non-forest land cover ([Bruijnzeel, 1990](#)), is usually discussed from the perspective of (i) global warming and global carbon budget ([Crutzen, 1987](#); [McElroy & Wofsy, 1986](#)), (ii) forests productivity, (iii) immense source of food, fibre, timber, medicine, and fuel ([Boom, 1985](#), [Lea, 1975](#)), and (iv) cultural and spiritual functions to the peoples of the tropics ([Jacobs, 1988](#)). However, it also affects the habitats for animals and plants and affects soil erosion. In the literature review, [Bruijnzeel \(1990\)](#) presents different views on the effects of deforestation on soil erosion. Some scientists suggest that deforestation in the tropics results in widespread soil erosion, floods, droughts, and desertification, while others explain increased soil erosion by poor land use practices and constructing activities following clearing of the forest. It is generally believed that in a forest, the ground is protected against splash erosion during intensive rainfalls. However, it was shown that a larger size of canopy drip may increase erosive power of rainfall ([Brandt, 1988](#); [Vis, 1986](#); [Wiersum, 1985](#)). The protective value of trees is rather related to development of a porous, well structured, and rich in organic matter litter layer ([Wiersum, 1985](#)), which favours infiltration and percolation of water. The loss of a tree cover is particularly harmful in the tropic regions, where high intensity rainfall can easily wash away topsoil humus layer. Soil loss from cultivated land can be several hundred times higher than from forested areas ([Newson, 1992](#)). Apart from severe losses of fertile soil, it obviously has damaging consequences for water quality with excessive sediment loads ending up in dams, lakes or coastal areas ([Pearce, 1992](#)).

Wetlands, accounting for about 6% of the total land area, are the most threatened of all landscape types. The significance of wetlands ecosystems is often reviewed in a context of their productivity, their role as birds and fish habitats and hydrological buffers ([Ramachandra et al., 2001, 2002](#)). Until the jump in economic development, wetlands were protected by their vastness, marginal direct usefulness for economic activities, and in particular by their remoteness. The pressure of population growth and ever growing need to satisfy humanity's demand for water, food, and energy caused intensive wetlands exploitation. Moreover, economical and industrial development improved access to wetland zones and increased their attractiveness as a new land resource.

Irrigation may cause water quality problems such as (i) salinisation, (ii) alkalinisation, (iii) erosion of irrigated land, (iv) loss of the fertility effect of river sediments in downstream areas following the construction of irrigation dams. Dissolved solids in water applied for irrigation can pose a threat of excessive salinisation of irrigated soils. Worldwide, 100 mln ha, or 40% of all irrigated land is at risk from salinisation or

waterlogging ([Hisgen, 1993](#)). FAO estimates that the loss of productive cropland due to salinisation is about 2 million hectares per year, and the World Commission on Environment and Development claims that millions of hectares of productive land are being abandoned annually ([WCED, 1987](#)). Less often mentioned is the water pollution that follows irrigation. To dissolve and flush away excessive salts, soils are treated with additional masses of water irrigation return flow. It transports the excessive amounts of dissolved solids to surface and groundwater. In some areas serious pollution problems for the aquatic ecosystems and for humans depending on the water source have occurred. Land degradation induced by deforestation, wetland transformation, overgrazing, and careless cultivation practices has enormous direct impact on hydrology through change in precipitation, soil erosion and transport of dissolved solids, etc. Indirectly, the quality of water bodies is also affected by losses of soil productivity and changes of vegetation cover.

Freshwater research and management efforts could be greatly enhanced by a better understanding of the relationship between landscape-scale factors and water quality indicators. This is particularly true in urban areas, where land transformation impacts stream systems at a variety of scales. Despite advances in landscape quantification methods, several studies attempting to elucidate the relationship between land use/land cover (LULC) and water quality have resulted in mixed conclusions. However, these studies have largely relied on compositional landscape metrics. For urban and urbanizing watersheds in particular, the use of metrics that capture spatial pattern may further aid in distinguishing the effects of various urban growth patterns, as well as exploring the interplay between environmental and socioeconomic variables. However, to be truly useful for freshwater applications, pattern metrics must be optimized based on characteristic watershed properties and common water quality point sampling methods. [Buck et al \(2004\)](#) studied the influence of land use on the water quality in stream integrity, which is scale dependent and varies in time and space. They examined the streams in two pasture catchments and a native grassland catchment on the south island of New Zealand, and included the range of stream sizes and sampling sizes in study. The study reveals that upstream land use is more influential in larger streams, while local land use and other factors may be more important in smaller streams. The authors used the geographical information system (ArcView, ESRI Ltd) and remote sensing techniques (ERDAS IMAGINE 8.5) to quantify the landscape structure and assess the influences of terrestrial ecosystems on river water quality.

[Griffith \(2002\)](#) reviews the recent advances in studies of landscape-water quality relationships using remote sensing techniques. The conclusion states that the increasing feasibility of using remotely-sensed data, landscape-water quality studies can now be more easily performed on regional, multi-state scales. The traditional method of relating land use and land cover to water quality has been extended to include landscape pattern and other landscape information derived from satellite data. Three items are focused in this article are:

- i.) the increasing recognition of the importance of larger scale studies of regional water quality that require a landscape perspective;

ii.) the increasing importance of remotely sensed data, such as the imagery derived normalized difference vegetation index (NDVI) and vegetation phenological metrics derived from time series NDVI data; and

iii.) landscape pattern. In some studies, using landscape pattern metrics explained some of the variation in water quality not explained by land use/cover.

However, in some other studies, the NDVI metrics were even more highly correlated to certain water quality parameters than either landscape pattern metrics or land use/cover proportions. Although studies relating landscape pattern metrics to water quality have had mixed results, this recent work applying these landscape measures and satellite derived metrics to water quality analysis has demonstrated their potential usefulness in monitoring watershed conditions across large regions.

[Kearns et al. \(2005\)](#) used a freely available LULC data set for the Santa Clara Basin, California, USA, and quantified landscape composition and configuration for sub watershed areas upstream of individual sampling sites, reducing the number of metrics based on: (1) sensitivity to changes in extent and (2) redundancy, as determined by a multivariate factor analysis. The first two factors, interpreted as (i) patch density and distribution and (ii) patch shape and landscape subdivision, explained approximately 85% of the variation in the data set, and are highly reflective of the heterogeneous urban development pattern found in the study area. Although offering slightly less explanatory power, compositional metrics can provide important contextual information.

[Gutierrez et al \(2004\)](#) assessed the watershed of Rio Conchos, USA. For this study satellite images were used to evaluate the ecological impacts of precipitation and land use on selected segments. The variation in the size and turbidity of reservoir, riparian vegetation, soil salinity and land use of watershed were analysed using Landsat TM images. These data were combined with the historical land use data and one time water quality and soil EC data. [Sikka et al \(2003\)](#) studied the hydrological response of watersheds to the conversion of natural grassland into bluegum (*Eucalyptus globulus*) in the catchments of hydroelectric reservoirs in the Nilgiris, South India. Low flow index (LFI) was used as a tool to study and quantify the effects of plantation on low flow regime. The planting of eucalyptus resulted in decreased low flow value as well as peak flow, which also increases the soil moisture loss. This study clearly reveals that caution needs to be exercised while planning large-scale conversion of plantations.

[Sharadha et al \(1998\)](#) studied the possible adverse effects of converting natural forested watershed with *Eucalyptus globules*. This study evaluates the implications of coppiced bluegum plantations on hydrological behaviour during the 10 years of the second rotation using the paired watershed technique in a montane temperate humid climate. The results show that the coppiced bluegum growth (1982-91) on the 59 % of the catchment area reduced the mean annual total runoff by 25.4 % and base flow by 27 % over the natural grassland. [Putuhena and Cordery \(2000\)](#) identified some hydrological effects of changing forest cover from eucalyptus to *Pinus radiata* in Australia . This study examines the effects of vegetation species change and growth rates on stream flow. It reveals that during the first 16 years growth of the *P.radiata* greatly affects the stream flow and other

water balance components. The clearance of forest affects the canopy and litter interception, which indirectly affects the stream flow.

[Selvaraj *et al* \(2003\)](#) studied the hydrology and fish diversity of River Tamiraparani in Tamil nadu, the study reveals that the species diversity of the fish depends on the quality and quantity of the water in the river. The Shannon-Weiner index shows that the fish diversity is inversely proportional to the pollution level. [Sivasubramani \(1999\)](#) carried out the water quality analysis of river Periyar in Tamil Nadu during 1989 to 1991. The study included the hydrological, physico-chemical and the biological analysis of the river water. The analysis revealed that owing to urbanization the quality of Periyar river water had deteriorated. The deterioration was shown by high values of hardness (90.5 to 220 mg/L), phosphorous (0.05 to 0.23 mg/L), conductivity (200 to 350.9 μ mhos), total coliform, etc in the downstream area due to sewage contamination. The flow rate varied from 0.02 to 5.4 m³/second. The peak flow rates were recorded in the months of August and November due to high velocity winds.

Gburek and Folmer (1999) investigated the chemical contribution and stream flow in an upland watershed on east-central Pennsylvania, USA. This study shows that the tributaries draining a forested ridge exhibited low ionic concentrations, while those originating within agricultural area exhibited higher ionic concentration (NO₃ - N up to 20 mg⁻¹). [Caruso \(2001\)](#) investigated the ecological impacts on river flow, water, and aquatic ecology. In this study it was found that the low flow in the agricultural catchments enhances the bacterial contamination, algal bloom due to increased nutrient (nitrogen and phosphorous) level due to lack of dilution of the nutrients.

[Jain \(2001\)](#) undertook hydro chemical study of mountainous watershed of river Ganga. The study reveals that the conductivity (330 μ S/cm) gets increased during the low flow periods and the total dissolved solids (2002 mg/L) are increased during the monsoon periods due to the high sediment concentration. The amount of nitrates and phosphates compounds is slightly high in the samples due to agricultural activities in the catchment area. [Korfali and Jurdi \(2003\)](#) investigated the water quality of the river systems of Lebanon. The study involved two different water bodies, one a free flowing river and the other a reservoir. The result revealed that the river with catchment area having agricultural and industrial activities had a high pH (8.4) than the free flowing river, which received domestic wastewater (high carbon dioxide content). The statistical analysis of parameters like bicarbonate, calcium, phosphate, sulphate, chlorides, metals like iron, zinc, lead, cadmium etc revealed significant differences in the water quality between the two water bodies. The study indicated that the differential water quality would be attributed to the nature of the water resources and the exposure to the contaminants. This is crucial in recommending intervention studies to protect the quality and promote the role of surface water use, as an integrated component of water management in Lebanon.

[Ravichandran *et al* \(1996\)](#) conducted the ecoregional water quality analysis in Tamiraparani river basin, South India. The methodology consisted of principal component analysis (PCA) of 23 features of the geological, geomorphological, basin morphometry and land-use aspects of the Tamiraparani basin defined in terms of 23

micro-basins. The PCA scores calculated on the five components were used to cluster the micro-basins into groups based on the similarity measure. The groups identified in the analysis were traced in the drainage map to delineate nine ecoregions. The PCA of the water quality of the identified nine-ecoregions revealed that three main processes are important for the water quality viz, geological origin of ionic richness variables, nutrient leaching from agricultural operations and the carbonate systems. [Hussain and Ahmed \(2002\)](#) identified the variability of physico-chemical parameters of River Pachin, Itanagar. The variability in the physico-chemical parameters for different flow periods maybe assigned to dilution of river water by dilution runoff, runoff, human activities and organic load. [Douterelo et al \(2004\)](#) performed water quality assessment by cyanobacteria in rivers of Spain. The experiment coupled with physico-chemical analysis of water with the cyanobacterial analysis revealed that the cyanobacterial population is significantly correlated with the increased nutritional status. The increase in the cyanobacterial population reduced the species richness of the community. The result confirms the suitability of cyanobacterial community for monitoring eutrophication in rivers.

[Sabater et al \(2000\)](#) studied the algal biomass distribution and its relationship with water quality and their environmental implications in Atlantic river, Spain. The experiment states that the algal biomass is high ($1000 \text{ mg chlorophyll - } a \text{ m}^{-2}$) in the open, nutrient (high bicarbonates and phosphates) rich habitat than the forested, nutrient poor habitat. Variations of dissolved oxygen were much higher (and reached hypoxia) at the site with higher biomass accumulation. The abundance of a fish community (dominated by cyprinids) more tolerant to hypoxia at that site would be attributed to the influence of algal biomass accumulation.

[Bharathi and Krishnamurthy \(1990\)](#) studied the effect of industrial effluent on the lotic habitat, River Kali in Dandeli, Karnataka. It was confirmed that the organic load in river water enhances the growth of indicator species like *Pandorina morum*, *Scenedesmus dimorphus*, *Cyclotella meneghiniana*, *Navicula spp*, *Oscillatoria chalybea* and *Euglena spp*. [Zafar \(1981\)](#) studied the algal species composition according to the nature of effluent. In this study author described the list of species according to source of effluent. According to this experiment different types of pollution from the industry can be identified with help of the indicator organisms, which are source specific in nature.

[Arvidsson \(1998\)](#) studied the influence of soil texture and organic matter on soil physical properties and crop yields in the agricultural fields in Sweden. The study showed that the organic matter makes the soil more resistant to compaction, so the higher organic matter content paves the way to air circulation and water permeability. [Sonakar \(2004\)](#) studied the physico-chemical properties of soils of Jabalpur as affected by the plantations of different tree species. The study reveals that there is an appreciable change in the C.E.C, exchangeable cations, nitrogen, phosphorous, pH and organic matter in the soil under *Tectona grandis* followed by *Dalbergiu sissoo*, *Cassia siamea* and *Albizia procera*. The results indicate that the existing vegetational cover determine the physico-chemical variation in soil. [Rawls et al \(2003\)](#) studied the effect of soil organic carbon on soil water

retention in USA. The results shows that the increase in organic matter content led to increase in the of water retention in sandy soil, and decrease in fine-textured soils.

[Chandran \(1993\)](#) studied the vegetational changes in the evergreen forest belt of Uttara Kannada District of Karnataka. In this investigation it was found that that endemism of Western Ghats is very high among the evergreen tree species than the deciduous one. The significant positive correlation exists between ever greenness and endemism. The process of vegetation changes affects the survival of the endemic plants, which leads to the loss of evergreen forests.

2. OBJECTIVES

Objectives of this study are:

- To study the land use pattern of catchment area of tributaries of River Sharavathi with remote sensing data and to identify the quantity and quality of the water supplied by eight tributaries to the reservoir.
- To study the nature of vegetation and soil quality of catchment and influence n the stream flow and water quality of selected twelve streams in three sub-basins Nandiholé, Nagodiholé and Yenneholé of River Sharavathi.



3. STUDY AREA

The Western Ghats or Sahyadris are the main hill range in peninsular India that run along the states of Maharastra, Goa, Karnataka, Kerala and Tamil Nadu starting from the river Tapti in the north to Kanyakumari in the south, extending over a length of 1300 km is one of the 18 biodiversity hot spots ([Myers, 1990](#), [Gadgil, 1996](#)) of the world. Since the ghats extend parallel to the coast rising up to the elevation of 900 – 1500 m above sea level, it forms a barrier to the monsoon winds from the southwest. The western side of the Ghats gets an average annual rainfall of 2000 – 4000 mm while the rainfall in eastern range is between 400 – 800 mm. These hill ranges are the main watershed in peninsular India from most of the rivers originates and flow into either Arabian Sea or Bay of Bengal.

The Sharavathi River basin lies in the latitude 75° 17'38" to 75° 17'38" and longitude 14° 25'08 to 13° 42'36". Sharavathi takes its origin in Ambutirtha in Tirthahalli Taluk of Shimoga district and it is the one of the major West flowing river of Karnataka. The total length of the river is about 132 km and has a drainage area of 2771 sq km. It joins the Arabian Sea at Honnavar of Uttara Kannada district. The river drops to a vertical fall of about 253 m in Jog. The portion of the river above the Linkanamakki dam is upstream and the rest as downstream. The major tributaries in upstream (Linganamakki reservoir catchment) as shown in Figure 4, are Nandiholé, Haridravathi, Mavinaholé, Hilkunji, Yenneholé, Hurliholé, and Nagodiholé.

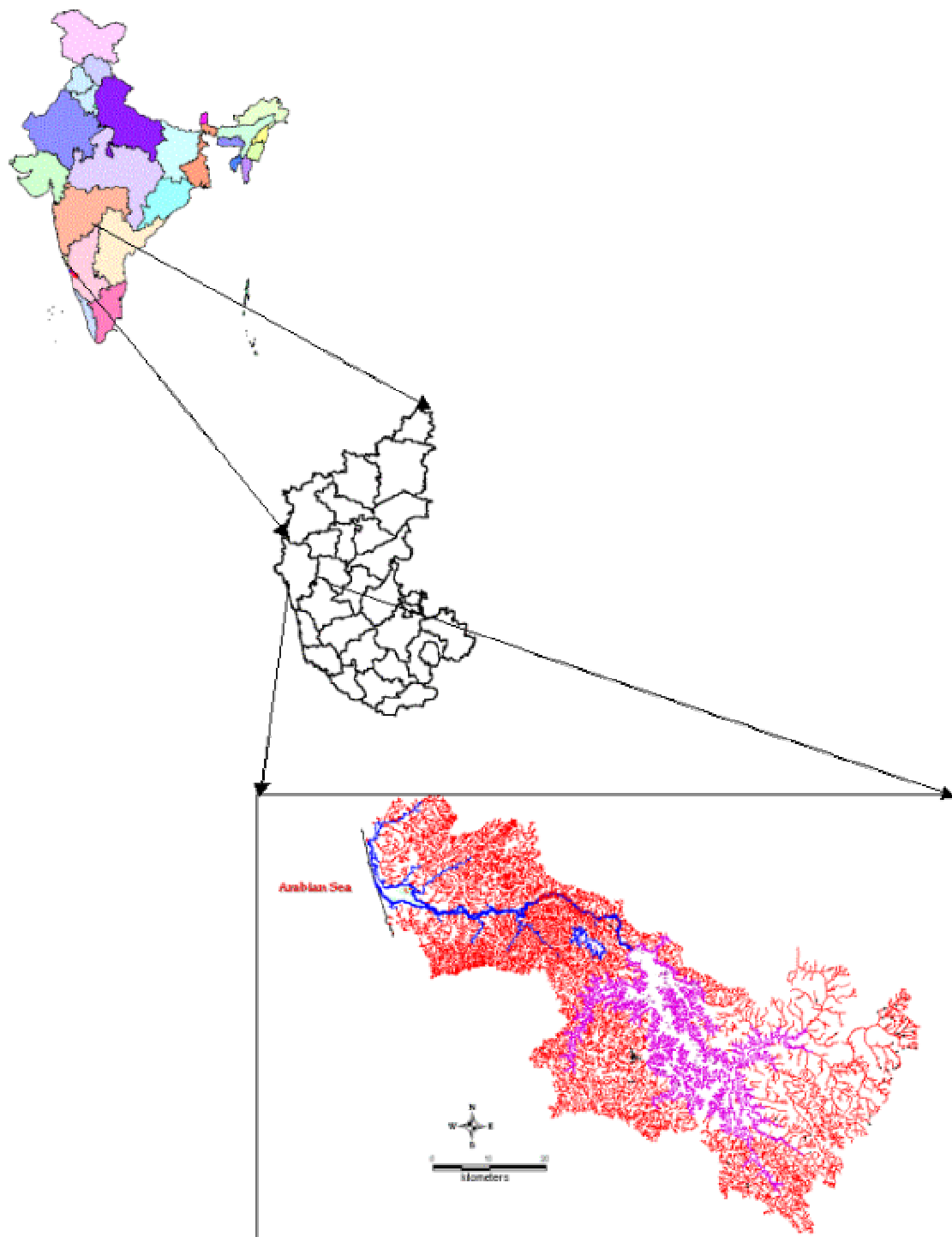


Figure: 3 Sharavathi River Basin.

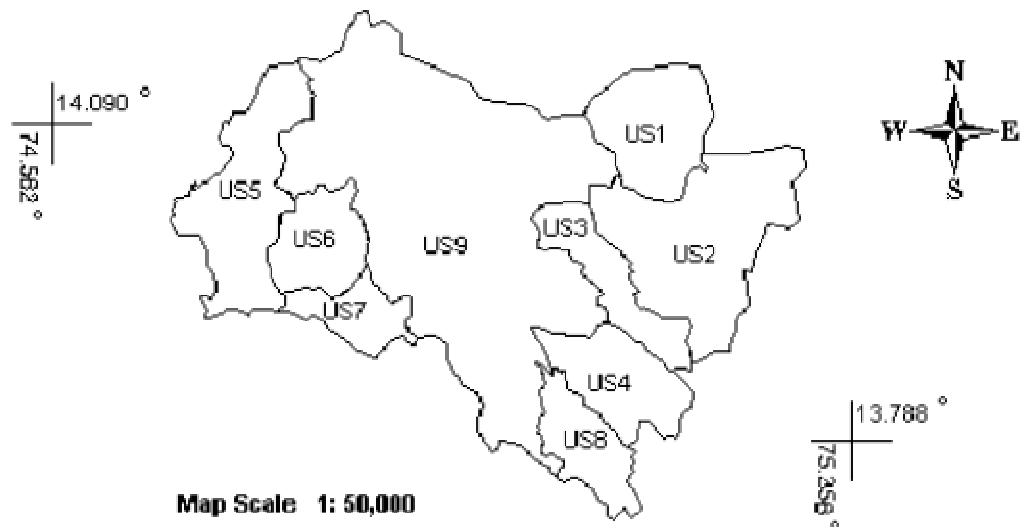


Figure: 4 Sub Basins in Upstream River Sharavathi

US1: Nandiholé	US2: Haridravathi	US3: Mavinholé
US4: Sharavathi	US5: Yenneholé	US6: Hurliholé
US7: Nagodiholé	US8: Hilkunji	US9: Linganamakki
	US9	

Sharavathi River Basin has the monsoon period from May to October, followed by winter from November to January and summer from February to May. The average rainfall variation in the sub-basin ranges from 1200 mm to 5000 mm. Average minimum and maximum temperature is about 15-38°C. Southwest monsoon brings 5000-8000 mm of rainfall per annum in Sharavathi River Basin.

Soils in the region are mainly lateritic in origin and tend to be predominantly acidic and reddish to brownish in colour. The various type of soil existing in the study area is clay loamy, clayey, clayey-skeletal, and loamy.

The study area is mainly made up of metamorphic rocks, some regions in western parts made up of residual capping and volcanics or meta-volcanics. Various metamorphic processes on the pre existing rocks form metamorphic rocks. Residual capping is the insoluble products of rock weathering. The volcanics and meta-volcanics are igneous rock formed by the cooling and crystallization of lava erupted from the volcanoes.

4. MATERIALS AND METHODS

4.1 WATER QUALITY STUDIES

Water Sample Collection: The monthly grab samples were collected in polyethylene container at the points where stream flow measurement was taken. The water sample for analysis was collected at each sampling station and subsequently stream flow was measured. The samples for phytoplankton analysis were collected in the same site by filtering 25 liter of water in bolting silk net No.25. In the case of tributaries the flow measurement and water quality samples were taken immediately the tributary confluence into the reservoir at monthly basis. The water samples were stored in 4° C. Following methods were employed for the estimation of various factors:

Table 1: Methodology for water Quality Analysis	
Parameters	Methods
pH	ELICO pH electrode
Electrical conductivity	ELICO conductivity bridge
Total dissolved solids	ELICO conductivity bridge (Electrical conductivity method)
Turbidity	Turbidity tube method: (Jal-Tara)
Hardness	EDTA titrimetric method (APHA, 1985: pp 210-213)
Calcium hardness	EDTA titrimetric method (APHA, 1985: pp 199)
Magnesium hardness	Magnesium by calculation (APHA, 1985: pp 228)
Sodium	Flame emission photometric method (APHA, 1985: pp 246)
Potassium	Flame emission photometric method (APHA, 1985: pp 237)
Acidity	NaOH titrimetric method (APHA, 1985: pp 265-268)
Alkalinity	H ₂ SO ₄ titrimetric method (APHA, 1985: pp 265-268)
Chlorides	Argentometric method (APHA, 1985: pp 287)
Nitrates	Phenol Disulphonic acid method (Trivedy and Goel, 1986: pp 61)
Phosphates	Stannous chloride method (APHA, 1985: pp 446-447)
Sulphates	Turbidimetric method (APHA, 1985: pp 467)

Biological analysis: Changes in water quality exert a selective action on the flora and fauna, which constitute the living population of water, and the effects produced in them can be used to establish biological indices of water quality ([Palmer, 1980](#)). Biological approaches to monitoring river water quality were introduced early in the 20 th century ([Kolkwitz and Marsson, 1908](#)), although they began to be widely adopted 40 years ago. In practice, the most important use of biological monitoring is to deal with situations where there is a range of contaminants whose biological effects may be synergistic or antagonistic, or where biological data give results that apparently contradict those yielded by chemical analysis ([Whitton, 1991](#)). Water quality affects the abundance, species composition, stability, productivity, and physiological condition of indigenous

populations of aquatic organisms. Therefore, the nature and health of the aquatic communities is an expression of the quality of the water, Biological methods used for assessing the water quality includes the collection, counting, and identification of the aquatic organisms ([APHA, 1985](#)).

Coliform test: This method is intended to indicate the degree of contamination of water with wastes. The water may serve as a vehicle for the transmission of waterborne diseases. Polluted water contains vast amounts of organic matter that serve as an excellent nutrient sources for the growth and multiplication of the microorganisms. The presence of non-pathogenic organisms is not of major concern, but intestinal contaminants of fecal origin are important. Analysis of water samples on a routine basis would not be possible if each pathogen required to detection. Therefore water is examined to detect *Escherichia coli*, the bacterium that indicates the fecal pollution. Since *Escherichia coli* is always present in faeces and whose normal habitat is the intestine of humans and other higher animals. *Escherichia coli*, the Gram negative, non-spore forming bacilli that ferment lactose with the produce H₂S gas. The medium contains Ferrous ammonium citrate, which reacts with the H₂S and turns in to black colour with in 48 hours.

Medium composition:

Peptone, Dipotassium hydrogen phosphate, Ferric ammonium citrate, sodium thiosulphate, 1ml Teepol and 50 ml distilled water.

Procedure:

1ml concentrated medium is absorbed on folded tissue paper; the tissue paper is kept in dry sterilised bottles; 20 ml of water sample to be tested is poured into this bottle; it is incubated at 30 - 37 ° C for 48 hours; if the water is contaminated by sewage the contents of the bottle turns black within 48 hours.

Phytoplankton:

The term 'plankton' refers to those microscopic aquatic forms having little or no resistance to currents and living free floating and suspended in open pelagic waters. The phytoplankton (microscopic algae) occurs as unicellular, colonial, or filamentous algae. Phytoplankton long has been used as indicator of water quality. Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species have been associated with noxious blooms, sometimes creating offensive tastes and odours or toxic conditions. Because of short life spans, phytoplankton responds quickly to environmental changes, and hence standing crop and species composition indicate the quality of the water mass in which they are found. They strongly influence certain non-biological aspects of water quality such as pH, colour, taste, and odour.

Sample collection and preservation: The sample were collected by cone shaped phytoplankton net made up of bolting silk net No 25 (200 meshes per

inch; inside measurement of mesh is 0.054mm). The wider end of the net is kept open by a metal hoop. A plastic 100 ml-receiving vessel closed the narrow end of the net. A known volume of the sample (25 litre) is filtered for phytoplankton. Sedimentation of phytoplankton was made by 4% formaldehyde. For identification of phytoplankton algal monographs by [Prescott \(1962\)](#) and Indian freshwater microalgae by [Anand \(1998\)](#) were followed. The counting of the phytoplankton was done by drop count method ([Trivedy and Goel, 1984](#)). The results are expressed as organisms per ml of sample.

[Palmer \(1969\)](#) proposed a pollution index based on phytoplankton algae and their tolerance to organic pollution. From information on pollution tolerant algae compiled from many authors, the genera and species considered significantly were found to fall in stable series. More than 60 genera and 80 species have been recorded to tolerate varying levels of organic pollution. The pollution status of water is determined based on their indices as shown in [Table 2](#).

Table 2: Palmer's Index.		
Pollution Index	Quality of Water	Remarks
20 or > 20	POSITIVE	High organic pollution
15 to 19	PROBABLE	Probable evidence of high organic pollution
< 15	NEGATIVE	Organic pollution is not high / Sample not representative / Some other factors interfering.

4.2 HYDROLOGICAL INVESTIGATION

Hydrology is the science that deals with the origin, distribution and properties of water on the earth including that in the atmosphere in the form of water vapour, on the surface as water, snow or ice, and beneath the surface as ground water. The study of hydrology deals with the three important phases of the hydrological cycles, namely rainfall, runoff and evaporation. A considerable portion of the water returned as stream flow, the movement of water under force of gravity through well-defined, semi permanent surface channels. The measurement, analysis, and interpretation of stream flow data are therefore important phases of hydrology ([Linsley et al., 1949](#)).

Velocity:

The velocity is the rate of flow of the water. The velocity of the stream water is calculated by floats method. The time taken for the float to reach the measured distance (usually one meter) is calculated by stopwatch. Velocity is expressed in meters per second (m/s)

$$\text{Velocity} = \frac{\text{Distance in meters}}{\text{Time in seconds}}$$

Discharge:

Discharge is the volume of water passing through any point in the watercourse over a specified period of time. The product of velocity and cross sectional area of a stream is known as discharge. Discharge is expressed in cubic meters/second (m^3/s)

$$\text{Discharge} = A * V$$

Where, A = Average cross sectional area of the stream (m^2)

Cross sectional area = width * depth

V = Flow velocity

Catchment area:

Using the contour lines on a topographical map (1:50000) the catchment boundaries are delineated. The ridge tops were followed to draw the boundaries of the catchment area around the streams that appears as downhill points in the toposheets. The boundary should be perpendicular to the contour lines it intersects. The tops of mountains are often marked as dots on a map and the location of roads, which follow ridges are other clues ([Ramachandra.T.V, 1999](#)).

4.3 CATCHMENT INVESTIGATION**4.3.1 GIS AND REMOTE SENSING**

To understand the land use pattern of the study area initially a base map was prepared using Survey of India toposheet (1: 50000 scale). The base map was then superimposed on the geocoded satellite data and visual interpretation of the false colour composite (FCC) was carried out in consultation with the Survey of India toposheet and ground truth in Idrisi 32 and map was digitized using Geographic Information System (software Mapinfo version 6.0).

4.3.2 VEGETATION ANALYSIS

The ideal method to sample the catchment vegetation is a combination of transect with quadrat. In this method the square plot of definite area (20 X 20 meter = 400 meter² = 0.04 hectare) are laid in a straight line transect with inter-quadrat distance of 20 meters. All the plants that are 30 cm or more in GBH [Girth at breast height or height at 130 cm] are considered as tree and identified, or collected if field identification was not possible and the samples were pressed for herbaria for future identification. The GBH was measured for each tree at the height of 130 cm above the ground and approximate height in meters ([Chandran 1999](#)). The cross sectional area of a tree estimated at breast height is called the basal area; it is normally expressed in m^2 . The sum of the basal areas of all trees on an area of one hectare is symbolized by $\text{Gm}^2 \text{ha}^{-1}$ ([Philip, 1994](#)).

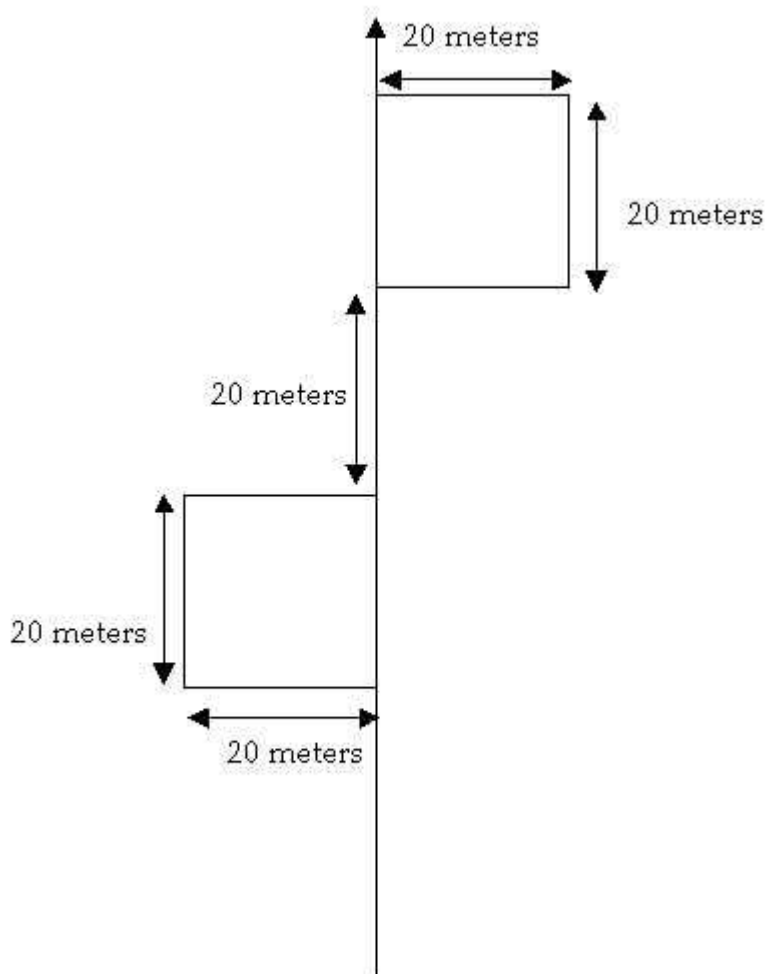


Figure 5: Transect cum quadrat method of Vegetation analysis.

The locality data for the vegetation sampling was obtained from the 1: 50000 toposheets published by Survey of India and a portable global positioning system gives the latitude, longitude and altitude of the locality.

Datasheet for Vegetation sampling:

Taluk: _____ Village: _____ Hamlet: _____ Stream name: _____ Sub-basin: _____

Latitude and longitude: _____ Forest type: _____

Serial Number	Species Name	Individuals	GBH (cm)	Height (m)	Remarks
1					
2					
3					

4					
5					

4.3.3 SOIL ANALYSIS

The soil quality concept evolved throughout the 1990s in response to increased global emphasis on sustainable land use and with a holistic focus emphasizing that sustainable soil management. Soil samples were collected, which were representative of the entire catchment area. Samples were collected 5 centimeters below the ground using an auger and core.

Soil quality assessments provide a better understanding and awareness that soil resources are truly living bodies with biological, chemical, and physical properties and processes performing essential ecosystem services. The following methods were employed for the estimation of various factors:

Table: 3 Methods for analysis of soil	
Parameters	Methods
pH	ELICO pH electrode
Electrical conductivity	ELICO conductivity bridge
Bulk density	Physical measurement with core
Soil moisture content	Gravimetric method
Water holding capacity	Physical measurement methods
Calcium	EDTA titrimetric method
Magnesium	Magnesium by calculation
Sodium	Flame emission photometric method
Available Potassium	Flame emission photometric method Ammonium Acetate (NH ₄ OAc) Method: (Marwin And Peach, 1951)*
Available phosphorus	Bray's method (Bray and Kurtz, 1945)*
Soil organic matter	Titrimetric determination (Walkley and black, 1934)*
* Original reference not cited; analysis carried out as per “ Baruah .T.C and Barathakur H.P. 1997 . A textbook of soil analysis, Vikas publishing house pvt Ltd. New Delhi”	

5. RESULTS AND DISCUSSION

LAND USE ANALYSIS

The land use patterns in each sub-basin were analysed with the remote sensing data and are listed in [Table 4](#) and [5](#) respectively. The same is depicted in [Figure 6](#). The quality of the water in the eight tributaries was assessed. The nature of vegetation influences the soil quality of catchment and also the stream flow. Water quality of selected twelve streams in three sub-basins Nandiholé, Nagodiholé and Yenneholé of River Sharavathi was also investigated to understand the quality aspects associated with the micro level anthropogenic activities.

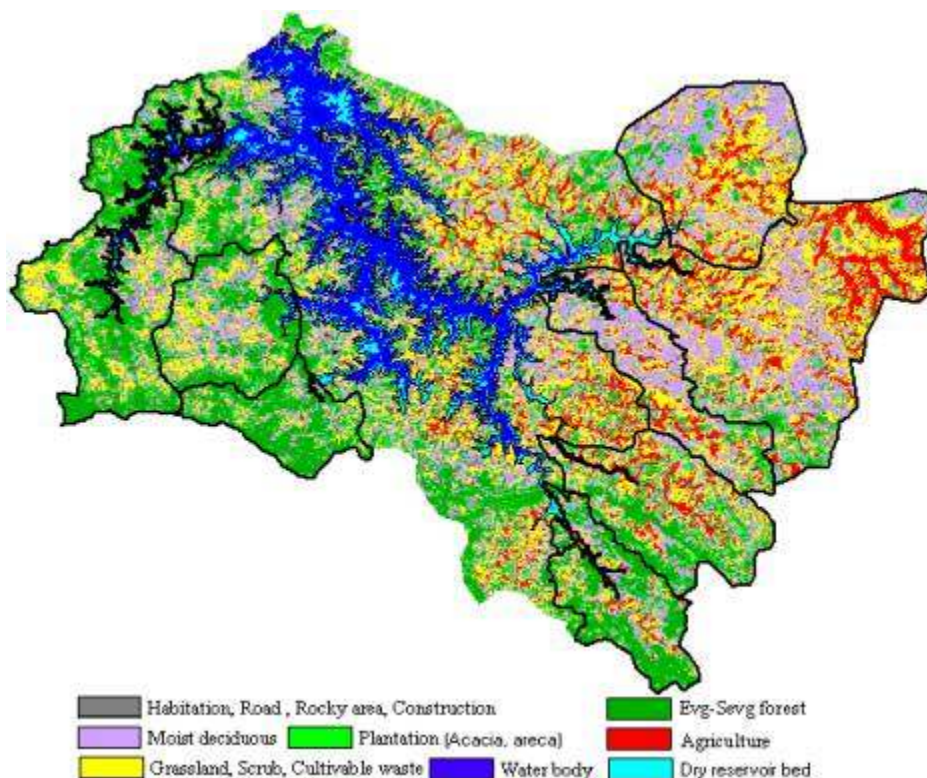


Figure 6: Land use analysis – Upstream of Sharavathi river basin

Nandiholé

The total area of Nandiholé sub basin is 143.6 km² in which 38.12 % area is covered by moist deciduous forest, followed by 30.56 % as grassland and scrub cultivable waste land. The habitation, road, rocky area and constructions occupied 11.14 %. Agricultural land and plantations occupied 11.33% and 5.52 % respectively. The amount of evergreen and semi-evergreen forest in Nandiholé catchment area ranks only 3.31 %. Finally the water bodies occupied 0.01% of the total area. This results show that the majority of catchment area occupied by disturbed forests and agricultural lands.

Haridravathi

In Haridravathi sub basin of the total area of 278.9 km² , 31.91 % is occupied by grassland, scrub and cultivable wasteland. Nearly 18.19 % of Haridravathi sub basin is used as agricultural land and 5.58 % for acacia and areca plantations. The evergreen and semi evergreen forests range about 2.28 % and deciduous forests ranges as 28.17 %. Habitation, road network and rocky area occupied 13.86 % of the total sub basin. The water bodies occupy 0.02 % of the total area of the sub basin.

Mavinaholé

The third sub basin from the eastern side of the reservoir is Mavinaholé, its total area ranges 95.1 km² . The maximum area of this sub basin covered by moist and deciduous forests about 41.62 %, followed by 24.68 % as grassland, scrub

and cultivable wasteland. Habitation, road network, rocky area and constructions consume 11.6 % in total area. The agricultural and plantation activities occupied 9.81 % and 7.88 % respectively. The area occupied by water bodies in Mavinaholé sub basin is 0.03 %. The evergreen and semi evergreen forest ranges about 4.37 % in total area.

Sharavathi

Sharavathi is the second largest sub basin in upstream with total area of 119.4 km² , in which grassland, scrub and cultivable wasteland occupy 20 % of the land. 22.95 % of the total area occupied by deciduous and moist deciduous forests. Habitation and road network occupied 12.49 % that is 14.91 km² . 19.16 % of the total area consists of evergreen and semi evergreen forests. Agricultural land and plantations occupied 10.33 % and 14.66 %.

Hilkunji

The total area of Hilkunji sub basin is 85.1 km² , in which 43.27 % of the land covered by the evergreen and semi evergreen forests. The deciduous and moist deciduous forest cover occupies 22.46 % in total area. Habitation, road network, rocky area and constructions make up 5.57 % of total area. Grassland and cultivable wasteland occupies 12.96 % of total cover. 11.5 % and 4.18 % of the total area of Hilkunji is used for plantation and agricultural activities.

Hurliholé

Habitation, road network, rocky area, construction, etc cover an area of 7.56 % of the 119 sq. Km of Hurliholé. 18.18% is covered by grassland, scrub, cultivable wastelands, etc. The semi-evergreen and evergreen forests make up 32.78% of the total area. Moist deciduous forests make up 27.91% whereas 10.74% of the total land area is planted with acacia and areca. The water bodies make up 0.88 % and the agricultural land covers about 1.97%.

Yenneholé

Yenneholé sub-basin covers an area of 68.6 sq. km. 10.1% of that area is covered by habitation, road, rocky area and construction. The grassland, scrub and cultivable wastelands make up 14.86% while semi-evergreen and evergreen forests make up 37.89%. Moist deciduous forests cover 19.76% of the area and acacia and areca plantation cover 15.8%. 0.14% of the total area of 68.6 km² is covered by water-bodies.

Nagodiholé

Nagodiholé is the one of the smallest sub basin in the up stream with total area of 68.6 km² . 52.14 % of the total area is occupied under evergreen and semi evergreen forests followed by 16.58 % of deciduous and moist deciduous forests. The land occupied for agriculture and plantations are 1.08 % and 13.66 % in total area. Habitation, roads, rocky area and constructions occupy 7.46 % of total area. The land with grassland, scrub and cultivable wastes are 9.07 % in total area. The water bodies in Nagodiholé sub basin are 0.01 % in total area of 68.6 km² .

Table 4: Land use pattern among of catchment area of eight tributaries of RiverSharavathi (in km ²)								
Sub basin	Class - 1	Class -2	Class- 3	Class- 4	Class- 5	Class- 6	Class- 7	Total
Nandiholé	15.99	43.88	4.75	54.74	7.92	0.014	16.26	143.6
Haridravathi	38.65	88.99	6.35	78.56	15.56	0.055	50.73	278.92
Mavinaholé	11.03	23.47	4.15	39.58	7.49	0.028	9.32	95.09
Sharavathi	14.91	24.36	22.87	27.40	17.50	0	12.33	119.4
Hilkunji	4.74	11.02	36.82	19.11	9.83	0	3.55718	85.1
Nagodiholé	5.11	6.22	35.76	11.37	9.37	0.006	0.74	68.6
Hurlihóhé	8.99	21.63	39	33.21	12.7	1.04	2.34	119.02
Yenneholé	6.92	10.19	25.99	13.55	10.83	0.096	0.93	68.54
Note: Class-1: Habitation, road, rocky area, and constructions. Class-2: Grassland, scrub, cultivable wasteland. Class-3: Evergreen to semi evergreen forests. Class-4: Moist deciduous forests. Class-5: Plantations. Class-6: Water bodies. Class-7: Agricultural land.								

Table 5: land use (%) in the catchment of eight tributarie							
Sub basin	Class – 1	Class -2	Class- 3	Class- 4	Class- 5	Class- 6	Class- 7
Nandiholé	11.4	30.56	3.31	38.12	5.52	0.01	11.33
Haridravathi	13.86	31.91	2.28	28.17	5.58	0.02	18.19
Mavinaholé	11.6	24.68	4.37	41.62	7.88	0.03	9.81
Sharavathi	12.49	20.41	19.16	22.95	14.66	0	10.33
Hilkunji	5.57	12.96	43.27	22.46	11.56	0	4.18
Nagodiholé	7.46	9.07	52.14	16.58	13.66	0.01	1.08
Hurlihóhé	7.56	18.18	32.78	27.91	10.74	0.88	1.97
Yenneholé	10.1	14.86	37.89	19.76	15.8	0.14	1.37
Note: Class-1: Habitation, road, rocky area, and constructions. Class-2: Grassland, scrub, cultivable wasteland. Class-3: Evergreen to semi evergreen forests. Class-4: Moist deciduous forests. Class-5: Plantations. Class-6: Water bodies. Class-7: Agricultural land.							

WATER QUALITY

The eight main tributaries of River Sharavathi were selected around the catchment area on the basis of their location and the streams feeding the Linganamakki reservoir. The tributaries feeding the reservoir on the eastern side include Nandiholé, Haridravathi and Mavinaholé. These tributaries can be grouped under the same category, as they confluence at reservoir from eastern part. The tributaries feeding on the southern side include Sharavathi and Hilkunji. The western tributaries are Nagodiholé, Hurlihóhé and Yenneholé. The major differences between these three groups are land use pattern and topography, the parameters that determine hydrological activities. The results of physico chemical parameters of the tributaries are shown in [Figures 7-11](#) and [Table 6](#).

The Nandiholé tributary water quality was analysed during January and February. The results show that the pH was slightly alkaline during February with a pH value of 7.95. Similarly total dissolved solids (69.22 mg/l), electrical

conductivity (138.3 μS), turbidity (25-50 NTU), alkalinity (64 mg/l), sodium (22.79mg/l) were high during the month of February compared to that of January. This is mainly due to the low stream discharge and subsequent concentration of the ions. Algal pollution index shows the probable evidence of organic pollution with the score of 14 and 15.

Haridravathi, one of the major tributary of River Sharavathi from the eastern side and its water quality results are listed in [Table 6](#). The pH value was slightly alkaline (7.54-7.98) for the both the sampling period. The increase in the dissolved ions is shown by the high TDS (65.94-76.02 ppm), electrical conductivity (130.8-152 μS), sodium (23.18-23.57), potassium (3.5-3.7), and turbidity values (25-50 NTU). Palmer's index gives the score of 2 and 11; it shows very less amount of organic pollution. The coliform test shows positive results through out the sampling period.

In Mavinahol  the pH ranges between 6.2-7.24, it shows the hydrogen ion concentration is near neutral condition. The TDS varies from 39.13- 58.51 ppm through out the study period; the increase in the dissolved ions concentration is also shown by electrical conductivity value (78-116.7 μS) and sodium and potassium values 15-18 mg/L and 4.15-6.03 mg/L. The Palmer's pollution index (2 and 9) shows no evidence for the organic pollution.

The pH of the tributary Sharavathi varied slightly (6.6 –7.13) through out the sampling period. And the conductivity was found in the range of 75.72-116 μScm^{-1} . The reason for this variation may be dissociation of minerals from soil or other human activities in tributary like washing and bathing. The total hardness and alkalinity were found in the range of 20-25 and 28mg/l, respectively. The concentration range of both the parameters were found within the soft water limits. Turbidity value ranges between 10-25 NTU. The sodium and potassium values are 12.7-13.29 and 2.77-2.87 mg/l respectively. The coliform test showed positive results through out the sampling period. The Palmer's algal pollution index shows the value of 8 and 7, indicating that organic pollution is not high.

The pH range of Hilkunji was near neutral condition (6.44-6.98). The amount of the dissolved ions are very less in this station, it is clearly shown by low TDS (21.52-25.54 ppm), electrical conductivity (43.07-50.84 μS). Algal index value for this station is recorded as nil and 8; it shows the absence of any pollution indicator species for first collection and very less score in second collection. The western tributary Nagodihol  showed near neutral pH values (6.45 –7.52), high turbidity values during the month of February (25-50 NTU), low values of alkalinity (12mg/l), acidity (5 mg/l), chlorides (4.9 and 5.9 mg/l), hardness (20 and 25 mg/l), calcium, magnesium, sodium, potassium etc. All these values were within permissible limits for inland water quality. The Palmer's algal index shows nil and very low amount of organic pollution with the scores of 0 and 8 respectively.

The pH range of Hurlihol  shows the neutral status of hydrogen ion concentration (6.6-7.0). The total dissolved solids ranges from 21.19-27.41 ppm. The electrical

conductivity values are in the range 42.46-54.44 μS . The alkalinity and acidity ranges 16-20 and 4-5 respectively. The coliform test shows positive results through out the sampling period indicating the faecal contamination. The algal pollution status determines no evidence of organic pollution.

The pH range of Yenneholé ranges with in the neutral condition 6.3-6.8. The total dissolved solids are in the range of 16-29.34ppm. The chloride content ranges from 3.9-7.4 mg/L. The sodium and potassium values range from 3.9-6.0mg/L and 1.2 mg/L respectively. Algal index shows the value of 0 and 4, which indicates the very less organic pollutant content in the water.

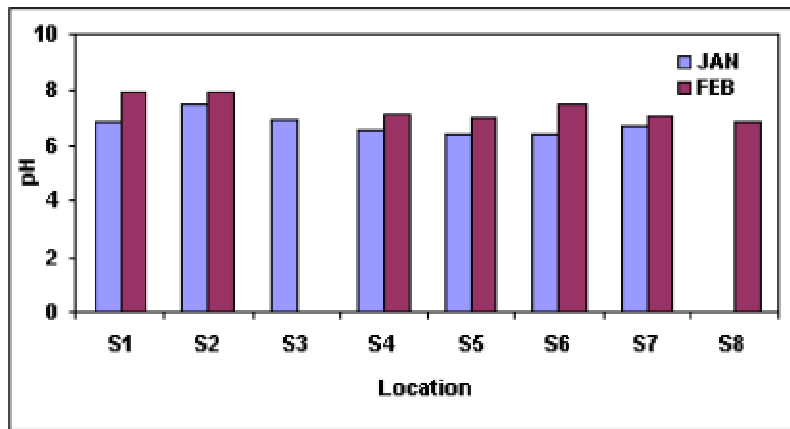


Figure 7: Variations of pH between the Sub basins

Table 6: Variation in Physico-chemical parameters in Tributaries of River Sharavathi																
	S1		S2		S3		S4		S5		S6		S7		S8	
	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB
W T-C°	29	30	28	30	28	29	30	34	29	33	n/a	33	28	33	29	33
pH	6.88	7.95	7.54	7.98	6.92	7.24	6.6	7.13	6.44	6.98	n/a	6.63	6.68	7.09	6.45	7.52
TDS - ppm	60.44	69.22	76.02	65.94	50.7	58.51	58.06	37.86	21.52	25.54	n/a	20.88	21.19	27.41	20.02	23.8
EC- $\mu\text{S}/\text{cm}$	121	138.3	152	130.8	100.3	116.7	116	75.72	43.07	50.84	n/a	41.55	42.46	54.44	40.13	47.38
Tur- NTU	25-50	25-50	25-50	25-50	25-50	25-50	10-25	10-25	10-25	25-50	n/a	10-25	10-25	10-25	10-25	25-50
Alk- mg/L	52	64	76	60	20	48	28	28	20	16	n/a	12	16	20	12	12
Aci-	15	16	25	12	15	20	5	16	10	8	n/a	4	5	4	5	4

mg/ L																
Chl- mg/ L	12.49	5.9	9.99	7.9	4.99	7.9	7.49	3.9	4.99	3.9	n/a	5.9	7.49	5.9	4.99	5.9
Har- mg/ L	35	40	75	50	45	50	20	25	15	20	n/a	10	20	20	25	20
Cal- mg/ L	20	25	50	30	25	15	10	5	10	10	n/a	5	10	5	5	10
Mag- mg/ L	15	15	25	20	20	35	10	20	5	10	n/a	5	10	15	20	10
Sul- mg/ L	3.827	3.04	6.49	6.666	4.028	3.742	3.01 9	2.57 2	3.26 9	2.80 6	n/a	2.33 9	2.90 8	2.105	2.361	2.105
Pho- mg/ L	0.02	0.02	0.00 6	0.015	0.002	0.004 1	0.02 3	0.01 3	0.00 7	0.00 6	n/a	0.00 8	0.00 6	0.006 1	0.010 2	0.010 5
Nit- mg/ L	0.59	0.53	0.5	0.52	0.49	0.47	0.52	0.55	0.48	0.48	n/a	0.48	0.49	0.54	0.46	0.48
Sod- mg/ L	25.02 6	22.79	23.5 7	23.18	14.84	18.43	12.7	13.2 9	9	7.76	n/a	3.97	7.85	5.43	5.23	4.36
Pot- mg/ L	4.55	3.36	3.76 2	3.56	3.86	6.03	2.87	2.77	2	1.98	n/a	1.28	1.78	1.18	1.48	1.48
Coli form	P	P	P	P	P	P	P	P	P	P	n/a	N	N	P	P	N
S1 = Nandiholé, S2 = Haridravathi, S3 = Mavinaholé, S4 = Sharavathi, S5 = Hilkunji, S6 = Yenneholé, S7 = Hurliholé, S8 = Nagodiholé.																
WT; Water Temperature, TDS; Total Dissolved Solids, EC; Electrical Conductivity, Tur; Turbidity, Alk; Alkalinity, Aci; Acidity, Chl; Chlorides, Har; Hardness, Cal; Calcium, Mag; Magnesium, Sul; Sulphates, Pho; Phosphates, Nit; Nitrates, Sod; Sodium, Pot; Potassium, Coliform = P; Positive & N; Negative																

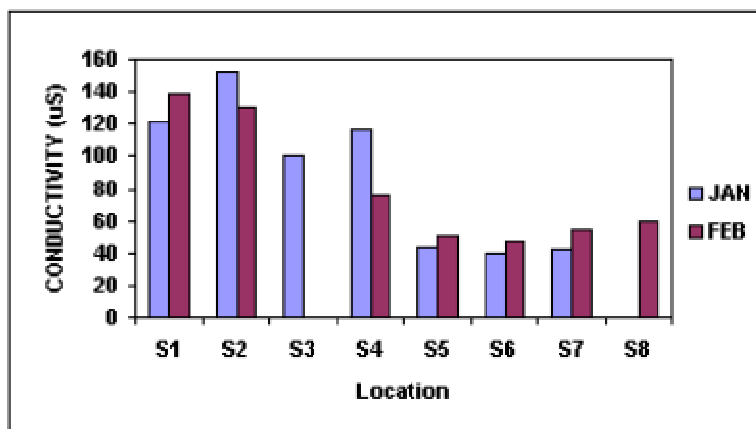


Figure 8: Variations of Conductivity between the Tributaries

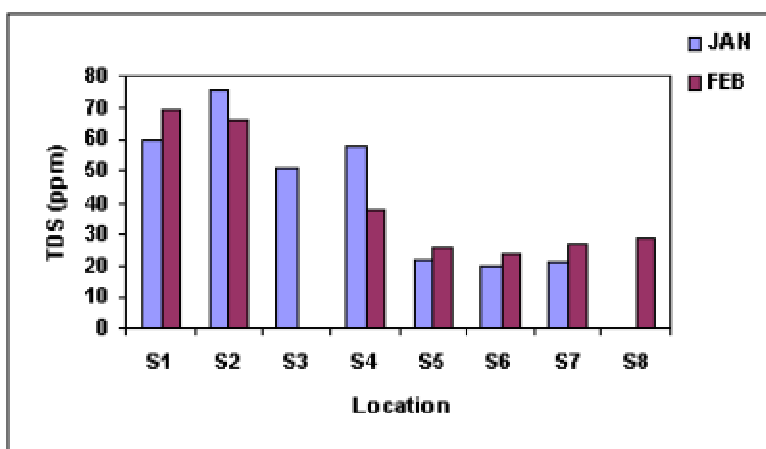


Figure 9: Variations of TDS between the Tributaries

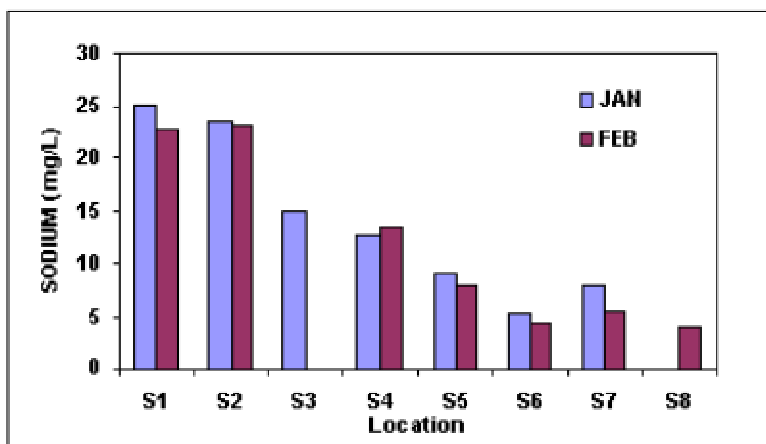


Figure 10: Variation of Sodium between the Tributaries

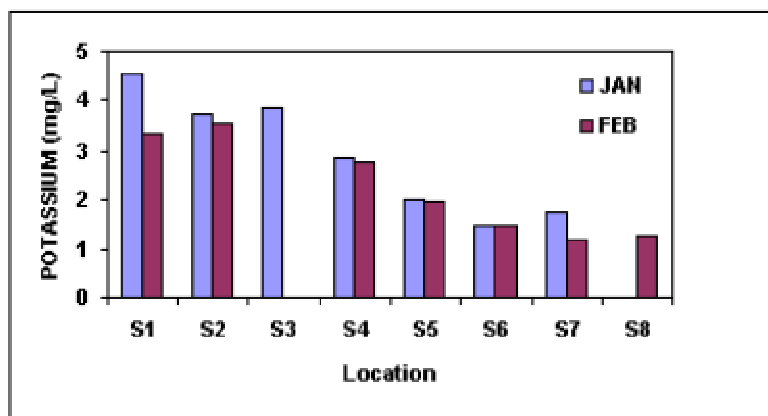


Figure 11: Variation of Potassium between the Tributaries

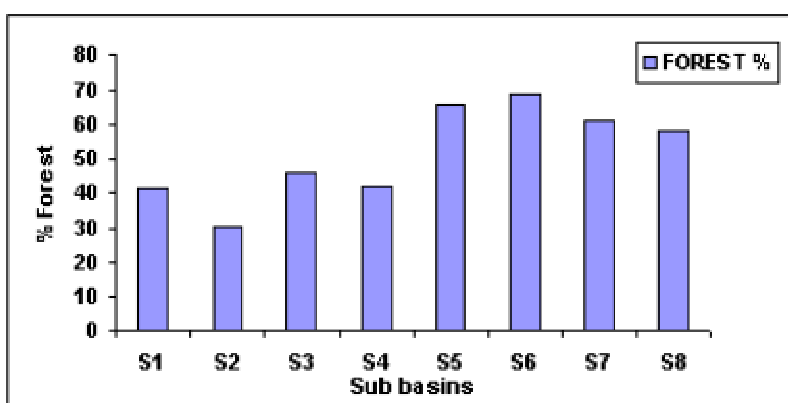


Figure 12: Percentage Forest in the catchment of the Tributaries

STREAM FLOW

The stream flow analyses show a wide variation between the tributaries of eastern and western side of the reservoir. In Nandiholé stream flow was 0.04 and 0.0018m³ /second for the month of January and February. It shows drastic change between the first and second collection. In Haridravathi first month stream flow was 0.07 m³/second and followed by 0.01 m³ /second. Mavinaholé, the third tributary from eastern side showed 0.17 m³ /second during the first observation and flow was stopped during the second collection. 0.38 m³ /second and 0.06 m³ /second were the flow rate observed in Sharavathi. It is one of the perennial water sources in the study area, but the varied stream flow between months shows the anthropogenic pressure (creating bunds for agriculture) on the aquatic ecosystem. In Hilkunji the first observation shows the discharge of 0.45 m³ /second and in second observation it reduced half in to 0.24 m³ /second. Incase of the Hurliholé the discharge measured for the first observation is 0.24 m³ /second and followed by 0.11 m³/second in second month. Due to inaccessibility only February month discharge is available for Yenneholé, during this time it shows a discharge rate of 0.24 m³ /second. The highest stream flow observed across the upstream was at Nagodiholé. During the first collection it shows 0.92 m³ /second and on the second observation it was 0.5 m³ /second.

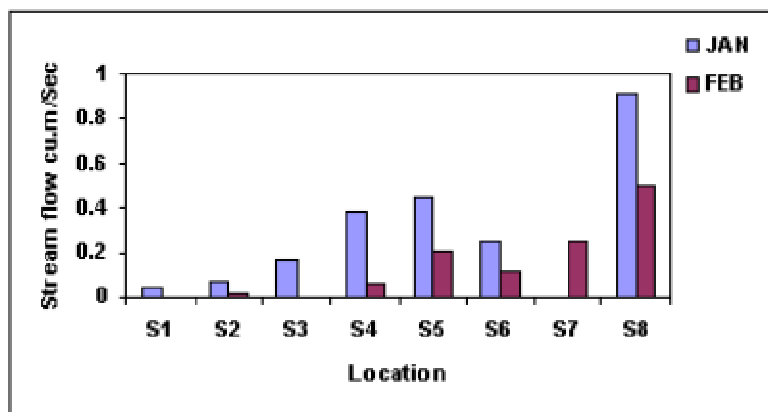


Figure 13: Variation of Stream flow between the Tributaries

RAINFALL

The average rainfall variation between the sub basins was computed by last 20 years rainfall data. The annual rainfall in Nandihol  (S1) and Haridravathi (S2) sub basins ranges between 1500 –2000 mm. In Mavinhol  (S3) the annual rainfall ranges between 2500 –3000mm. Sharavathi (S4) sub basin receives rainfall of 3000-4000 mm per annum. Hilkhunji (S5) sub basin receives annual rainfall of 4000-5000 mm. The annual rainfall in Yennehol  (S6) sub basin ranges about 5000-7000mm. Hurlihol  (S7) sub basin receives 4000-5000 mm of rainfall per year. Nagodihol  receives 5000-6000 mm of rainfall annually. It shows that the eastern side sub basins receive least rainfall while comparing with the western side sub basins of Sharavathi river basin. The variation of rainfall across the sub basins is shown in [Figure 14](#).

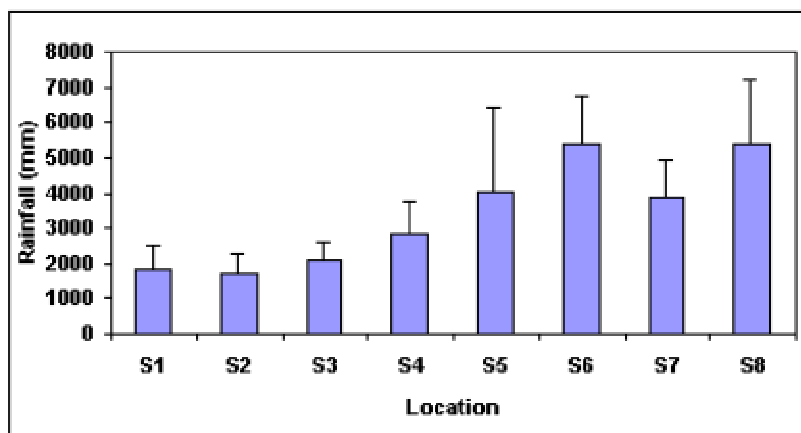


Figure 14: Annual rainfall across the sub basins of Sharavathi River Basin.

MICRO SCALE ASSESSMENT

Vegetation Analysis

The vegetation analysis in the catchment area of the streams of Nandihol , Nagodihol  and Yennehol  reveal inter relationships among various components of the ecosystem. The catchment area of the streams of Nandihol  sub basin shows the very low Western Ghats endemism (4.35%, 8.62%, 11.71%, and 38 %) and evergreenness (0%, 11.76%, 18.97%, and 15.56 %) and it indirectly shows that the disturbance in the forest of

catchment area. The vegetation analysis in Nagodiholé sub basin stream catchment shows the endemism values of 59.62%, 73.58% and 87.5 % and evergreenness values in the range of 90.38%-94.34 %. The endemism of trees in the catchment area of Yenneholé sub basin was 44.44%, 62.71% and 75.36 % and the percentage evergreenness is 88.14%, 88.89% and 94.2 %. The total basal area for each quadrat was calculated and it was seen that wherever the basal area was high, the stream flow was also high as shown in the [Figure 20](#). The endemism and evergreenness was positively co-related with stream flow as shown in the [Figures 18](#) and [19](#). The sub-basin with higher endemism, evergreenness and the total basal area has streams with higher stream discharge. Catchment of Nagodiholé and Yenneholé streams showed higher endemism, evergreenness and total basal area and thus in the stream discharge, whereas in Nandiholé stream discharge decreased and so did the endemism, evergreenness and total basal area of trees. This corroborates that the status of catchment vegetation is correlated to the water discharge, which is shown in [figure 15](#) - [17](#).

The stream flow measurement varied radically between the first and second order streams of the three sub basins as shown in the [Figures 15](#) - [17](#) . In Nandiholé sub basin, during the study period, the streams Byadarakoppa (NA3) and Hosur (NA4) dried up during January and February. In the first month stream discharge observation Hebbailu shows $0.0011 \text{ m}^3/\text{second}$ and consecutive month as $0.0002 \text{ m}^3/\text{second}$. Hunsevalli stream in this sub basin shows $0.1 \text{ m}^3/\text{second}$ for the month of January and $0.26 \text{ m}^3/\text{second}$ during second observation. In this stream the discharge rate was increased during the second month, because people opened the bunds after the irrigation. It shows the anthropogenic activities in the stream by the human activities.

In Nagodiholé sub basin, Alagodu stream shows $0.24 \text{ m}^3/\text{second}$ and $0.19 \text{ m}^3/\text{second}$ stream discharges during the study period. In Gurta stream the first month stream discharge was $0.1 \text{ m}^3/\text{second}$ and during the second observation it was $0.7 \text{ m}^3/\text{second}$. In Chengavalli stream the stream discharge for January and February was 0.08 and $0.04 \text{ m}^3/\text{second}$ respectively. The fourth stream selected in Nagodiholé sub basin was Kodachadri in this stream January month discharge was $0.1 \text{ m}^3/\text{second}$ and in February it showed $0.065 \text{ m}^3/\text{second}$.

The streams selected in Yenneholé sub basin are Keshvapura, Chengodu, Beligar and Karini. Keshvapura stream showed the discharge of 0.03 and $0.02 \text{ m}^3/\text{second}$ for the month of January and February. In Chengodu January month stream discharge was $0.08 \text{ m}^3/\text{second}$ and in February it was recorded as $0.01 \text{ m}^3/\text{second}$. In the first month stream discharge observation in Beligar shows $0.1 \text{ m}^3/\text{second}$ and consecutive month as $0.05 \text{ m}^3/\text{second}$. Karini stream in this sub basin shows $0.02 \text{ m}^3/\text{second}$ for the month of January and $0.0039 \text{ m}^3/\text{second}$ during second observation.

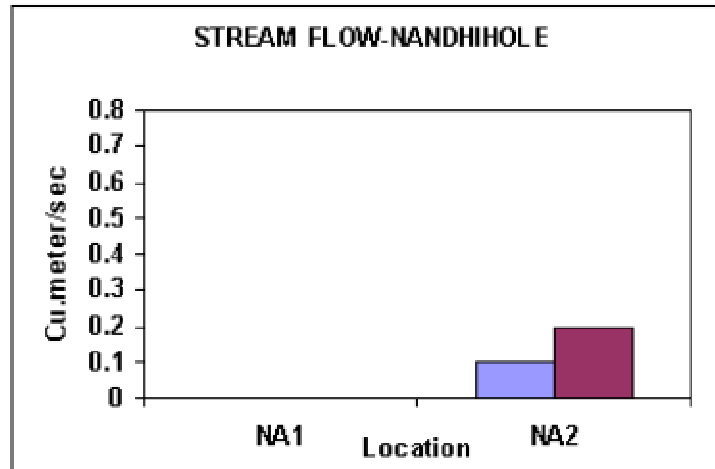


Figure 15: Variation of Stream flow in Nandihol  sub basin

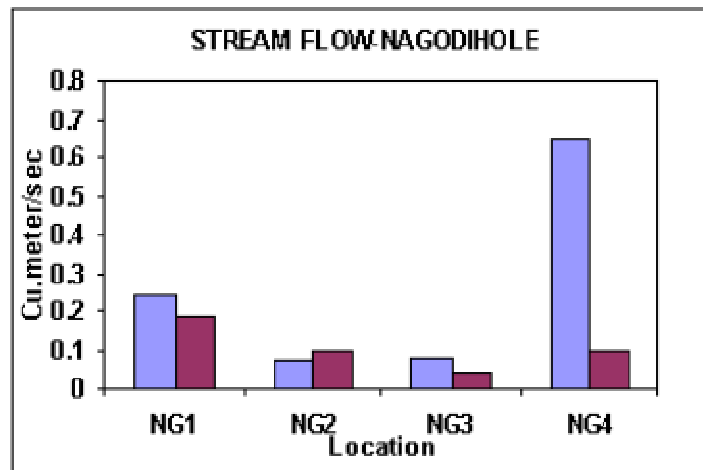


Figure 16: Variation of Stream flow in Nagodihol  sub basin.

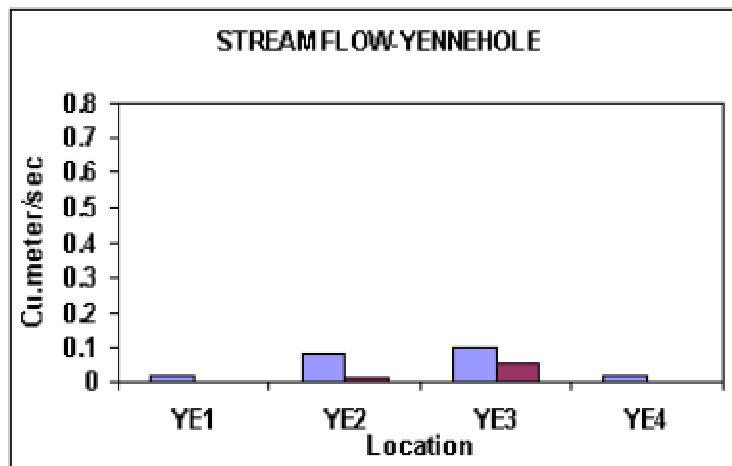


Figure 17: Variation of Stream flow in Yennehol  sub basin

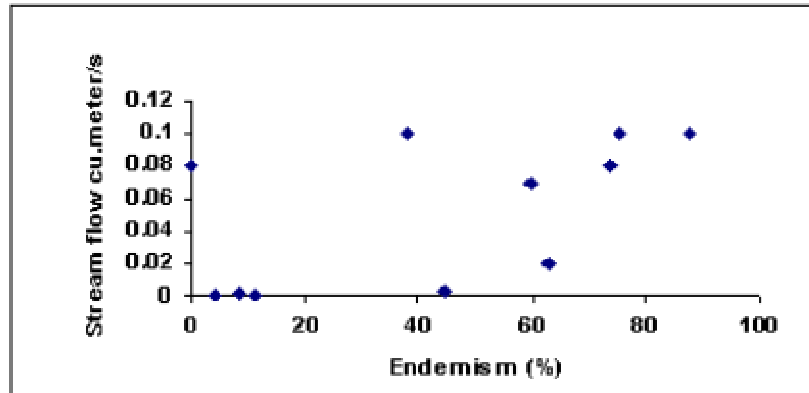


Figure 18: Correlation between Endemism and Stream flow

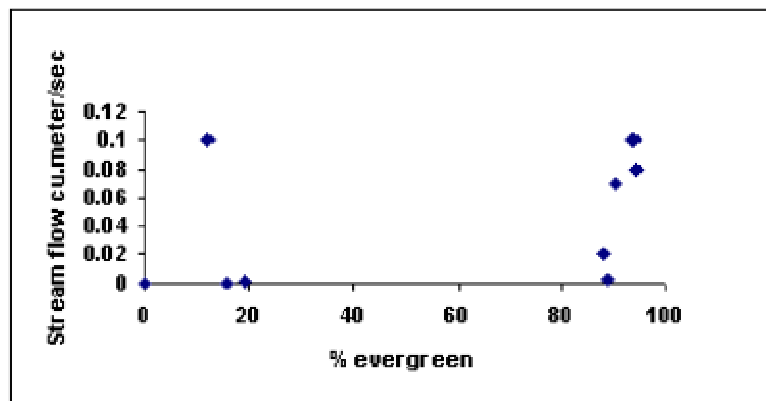


Figure 19: Correlation between Evergreeness and Stream flow

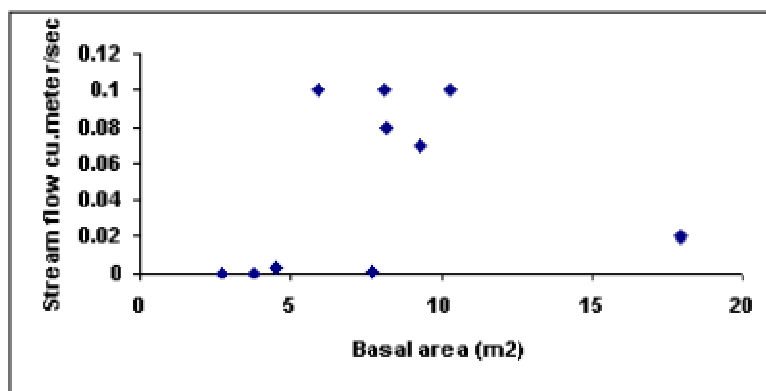


Figure 20: Correlation between Basal Area and Stream flow

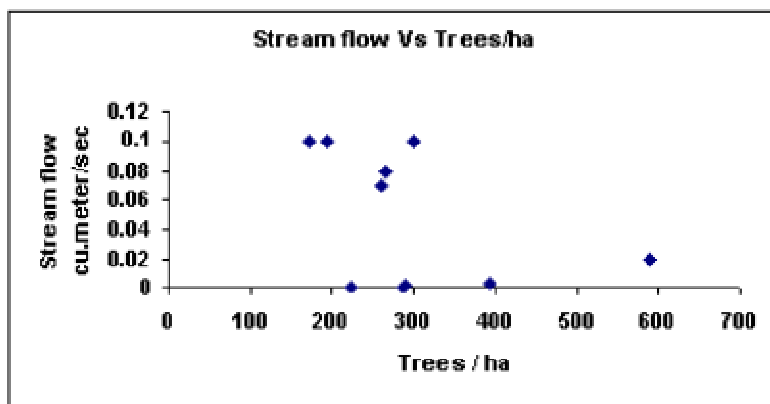


Figure 21: Correlation between Trees/ha and Stream flow

Water quality analysis

The sub-basin wise physico-chemical and biological analysis of the water samples is presented in [Tables 7-9](#). The streams in the sub-basins were selected based on their topography, land-use pattern and rainfall. The month-wise variations in the physico-chemical parameters across the three sub-basins are given in [Figures 25 –33](#).

Nandiholé

The pH of the water was slightly alkaline with values ranging from 6.7 to 7.65, which was also reflected in increased alkalinity (46 – 100 mg/l). The total dissolved solids during all the months in all the streams in Nandiholé sub-basin were high (TDS – 53.37 – 110.6 mg/l). This was shown by high Electrical conductivity (106.1 – 221.4 μ S) and turbidity (> 25 - >100 NTU), which exceeded the Indian standard values for inland waters. These high values are mainly due to the increased agricultural run-off from the catchment area. The vegetation studies in the catchment area show a very less percentage of endemism and evergreenness, which shows the quality of forest situated in the catchment area. The sub-basin is characterized by low altitude and low rainfall with an average of 1800 mm. Consequently, the forest area in the sub-basin is only 41% and the rest of the area is cultivated. Hence, the anthropogenic activities in the catchment area of the streams in the sub-basin contribute to the pollution load in the water. The coliform test was positive for all the streams during all the months in the sub-basin indicating faecal contamination. Palmer's algal pollution index shows the probable evidence for organic pollution in both the locations; the score range from 6-17.

Nagodiholé

In Nagodiholé sub-basin the streams Alagodu (NG1), Garta (NG2), Chengavalli (NG3) and Kodachadri (NG4) are selected for study. The pH in all the streams was slightly acidic to neutral (5.73 – 7.09). The stream flow was present throughout the sampling period. The total dissolved solids (15.24 – 32.41 mg/l), electrical conductivity (30.47 – 64.75 μ S), turbidity (10-25 NTU) were within the standard values for inland waters. The other parameters like nitrates (0.219 – 0.5 mg/l), phosphates (0.005-0.028 mg/l),

sulphates (1.754 – 3.4 mg/l), sodium (2.71- 6.768mg/l), potassium (0.891-2.69 mg/l), nitrates (0.214 – 0.51 mg/l), etc were within the permissible limits. The faecal coliform test was negative for most of the streams. Algal pollution status confirms that there is no evidence for the organic pollution. The results of this sub-basin reveal that there is no inflow of contaminants to the streams and there is no anthropogenic influence in the sub-basin.

Yenneholé

The Yenneholé sub-basin included the streams of Karini (YE1), Chengode (YE2), Beligar (YE3) and Keshavapura (YE4). The pH was nearly neutral with values ranging from 6 – 7.26. The total dissolved solids (20.15 – 29.1mg/l), conductivity (40.1-58.3 μ S), turbidity (10-25 NTU), alkalinity (8-16mg/l), acidity (4-10mg/l), chlorides (3.9 – 9.9 mg/l), phosphates (0.004-0.008mg/l), etc were within the standard limits for inland water samples. The stream flow was present throughout the sampling period. Palmer's algal pollution index confirms that there is no evidence for the organic pollution with the scores of 2-7. The results show that there is no pollution load in the streams in the Yenneholé sub-basin. The [Figures 21 – 29](#) represent the results of physico-chemical analysis of the three sub-basins.

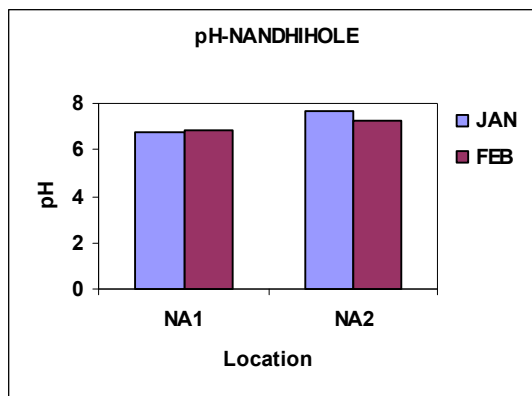


Figure 22

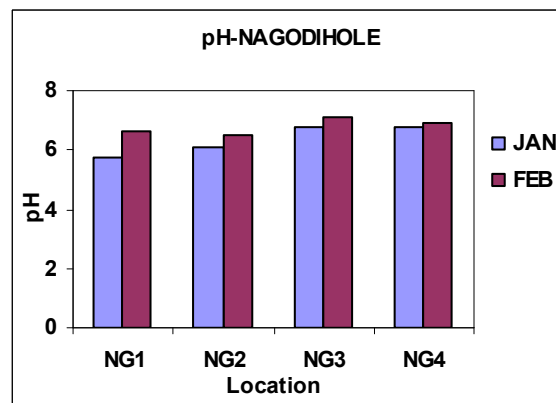


Figure 23

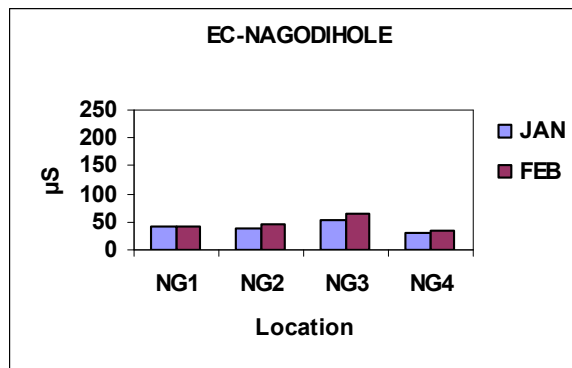
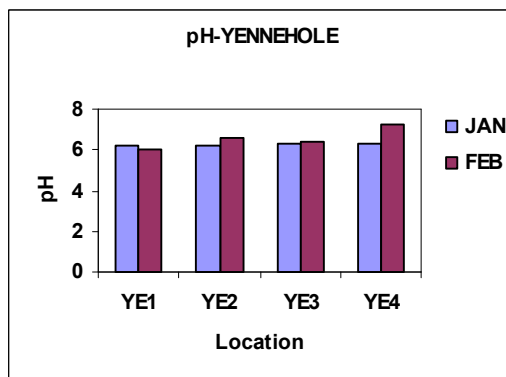


Figure 24

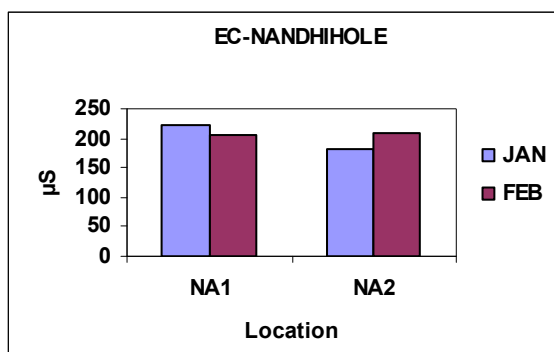


Figure 26

Figure 25

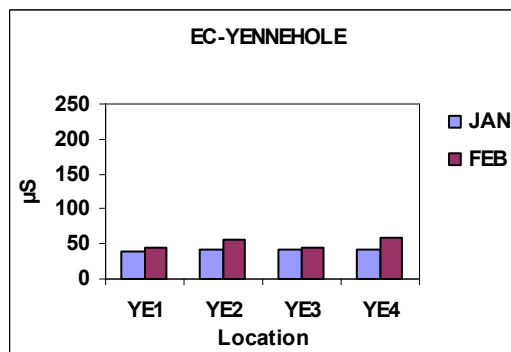


Figure 27

Table 7: Physico-chemical characteristics of water from Nandiholé sub basin				
	HEBBAILU (NA1)		HUNSEVALLI (NA2)	
	JAN	FEB	JAN	FEB
Temperature- °C	31	31	32	29
PH	6.78	6.828	7.64	7.27
TDS-ppm	110.6	103.7	91.07	104
EC- μs	221.4	207	181.8	207.8
Turbidity-NTU	25-50	25-50	25-50	25-50
Alkalinity-mg/l	46	88	92	100
Acidity-mg/l	15	28	10	24
Chlorides-mg/l	9.9	9.9	12.4	13.9
Hardness-mg/l	40	15	75	100
Calcium-mg/l	25	15	45	55
Magnesium-mg/l	15	0	30	45
Sulphates-mg/l	3.482	3.625	4.002	3.508
Phosphates-mg/l	0.01	0.016	0.006	0.0192
Nitrates-mg/l	0.56	0.59	0.436	0.52
Sodium-mg/l	21.24	35.01	31.71	27.83
Potassium-mg/l	5.24	13.06	6.63	7.82
Coliform	Positive	Positive	Negative	Positive

Table 8: Physico-chemical characteristics of water from Yenneholé sub basin								
	KARINI (YE1)		CHENGODE (YE2)		BELIGAR (YE3)		KESHVAPURA (YE4)	
	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB
Temperature- °C	25	27	25	24	28	32	26	28

PH	6.23	6	6.2	6.63	6.29	6.44	6.3	7.26
TDS-ppm	20.15	22.66	22.85	27.93	21.48	22.01	21.36	29.1
EC-μs	40.1	45.17	42.49	55.28	42.9	44	42.52	58.3
Turbidity-NTU	10-25	10-25	10-25	10-25	10-25	10-25	10-25	10-25
Alkalinity-mg/l	16	16	12	12	8	12	16	16
Acidity-mg/l	5	8	5	5	10	4	5	8
Chlorides-mg/l	4.99	3.9	7.49	7.49	7.49	5.9	4.99	9.9
Hardness-mg/l	15	30	20	20	20	20	10	30
Calcium-mg/l	10	5	10	10	10	10	5	15
Magnesium-mg/l	5	25	10	10	10	10	5	15
Sulphates-mg/l	1.684	1.52	2.257	2.339	1.684	1.52	2.069	2.572
Phosphates-mg/l	0.004	0.006	0.007	0.0073	0.008	0.0073	0.0072	0.00761
Nitrates-mg/l	0.42	0.47	0.49	0.56	0.41	0.45	0.41	0.48
Sodium-mg/l	5.82	4.07	5.43	5.33	6.98	3.97	6.01	6.59
Potassium-mg/l	0.79	0.69	1.72	2.97	2.178	0.89	1.68	2.67
Coliform	Negative	Positive	Negative	Positive	Positive	Positive	Positive	Positive

Table 9: Physico-chemical characteristics of water from Nagodiholé sub basin								
	ALAGODU (NG1)		GARTA	(NG2)	CHENGAVALLI (NG3)		KODACHADRI (NG4)	
	JAN	FEB	JAN	FEB	JAN	FEB	JAN	FEB
Temperature- °Cs	28	28	29	27	28	27	28	28
PH	5.73	6.63	6.07	6.51	6.77	7.09	6.75	6.93
TDS-ppm	20.67	20.16	18.58	22.3	26.56	32.41	15.24	17.37
EC-μs	41.41	40.27	37.26	44.63	53.38	64.75	30.47	34.72
Turbidity-NTU	10-25	10-25	10-25	10-25	10-25	10-25	10-25	10-25
Alkalinity-mg/l	8	12	12	12	24	20	8	8
Acidity-mg/l	5	4	5	4	5	4	5	4
Chlorides-mg/l	9.9	5.9	4.99	3.9	4.99	5.9	4.99	3.9
Hardness-mg/l	15	20	15	15	20	10	15	20
Calcium-mg/l	5	5	5	10	15	5	5	5
Magnesium-mg/l	10	15	10	5	5	5	10	15
Sulphates-mg/l	2.648	1.871	2.015	1.754	2.358	2.455	2.056	1.754
Phosphates-mg/l	0.0059	0.008	0.01	0.028	0.008	0.008	0.0049	0.0138
Nitrates-mg/l	0.46	0.51	0.42	0.5	0.48	0.57	0.39	0.49
Sodium-mg/l	6.98	3.2	4.94	4.07	4.17	6.01	6.59	2.71
Potassium-mg/l	1.485	1.18	1.28	1.38	0.891	1.58	1.683	1.08
Coliform	Negative	Positive	Positive	Positive	Negative	Positive	Negative	Positive

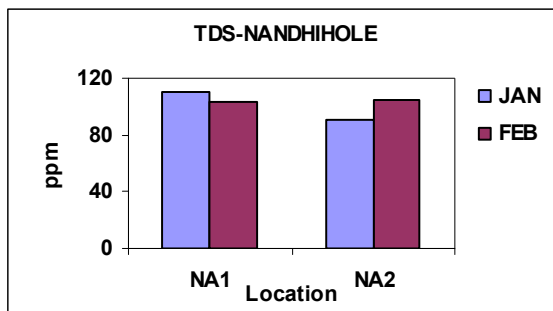


Figure 28

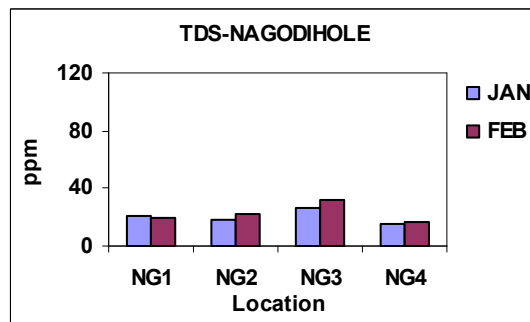


Figure 29

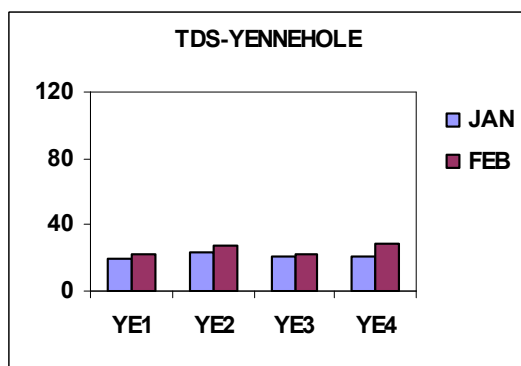


Figure 30

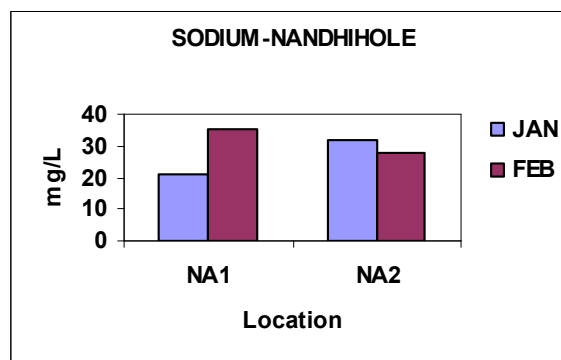


Figure 31

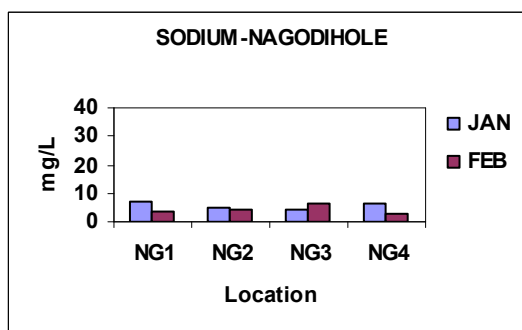


Figure 32

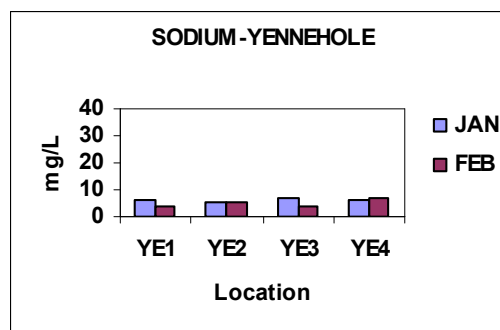


Figure 33

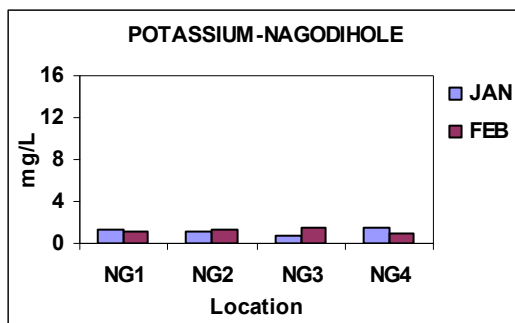


Figure 34

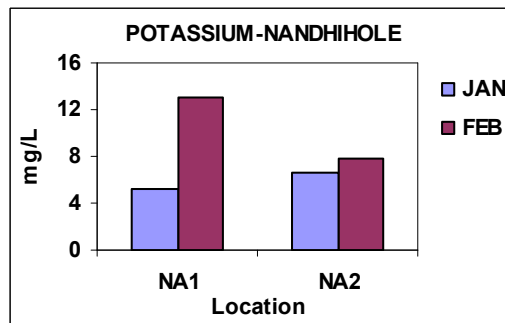


Figure 35

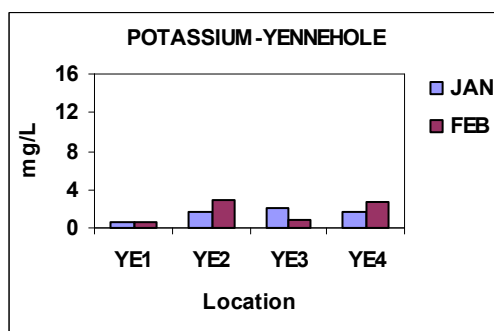


Figure 36

Soil Analysis

Soil samples representative of the Nandiholé sub-basin was collected from catchment area of Byadarakoppa, Hunsevali, Hosur, Hebbailu and Jamburmane and they were subjected to physico-chemical analysis. The soil pH was acidic to moderately acidic (pH - 4.831 – 6.777), which may be due to the agricultural activities in the catchment area. The bulk densities of the soil in the sub-basin were high ranging from 1.197 g/cc – 1.758 g/cc. In these areas the water holding capacity was quite low with values ranging from 9.367 – 31.93 %. The percentage of organic matter in all the sampled areas was less (Organic matter – 0.23 – 4.03%). The relative concentration of the other elements were Potassium > Phosphates > Calcium > Magnesium > Sodium. The low concentrations of these ions show the degraded quality of the soil due to various anthropogenic activities, mainly agriculture in the catchment area. The variations in the physico-chemical parameters are presented in [Table 10](#).

The representative soil samples collected from the Nagodiholé sub-basin subjected to physico-chemical analysis revealed that the soil is slightly acidic with pH values of 5.26 – 6.32 and high organic content. Such soils are optimal for plant growth and microbial activity. The soils of Nagodiholé sub-basin had high moisture content (9.3 – 21.23 %) and high water holding capacity ranging from 19.92 % to 44.135%. The concentration of other elements like calcium, magnesium, potassium, sodium, etc revealed that the soil was fertile.

The soil samples collected in the sub-basin show high moisture content (14.3-16.3%), high water holding capacity (32.804 – 38 %) and high organic matter (1.27 – 5.88%). The soils were rich in potassium (42 kg/ha – 100 kg/ha) and phosphates (0.64 kg/ha – 1.9 kg/ha), revealing a highly productive soil.

The difference among the sub-basins in the soil and water quality can be attributed to the land-use pattern in the catchment area, rainfall pattern and topography. The streams of the Nandiholé sub-basin was organically polluted as seen by high values of pH, alkalinity, electrical conductivity, total dissolved solids, sodium, potassium, palmer's index, coliform bacteria, etc whereas the streams in the Yenneholé and Nagodiholé sub-basin were relatively less polluted. This is mainly due to agricultural activities and the resultant run-off in the Nandiholé sub-basin. The catchment area of Nagodiholé and Yenneholé were characterized by the presence of evergreen, semi-evergreen and moist deciduous forests. The soil quality analysis revealed that the soil was productive in the Nagodiholé and Yenneholé sub-basins whereas the low concentration of essential ions in the Nandiholé sub-basin showed degraded soils.

Table 10: Physico-chemical characteristics of soil from Nandiholé (NA), Nagodiholé (NG) and Yenneholé (YE) sub basins.											
Location	Bulk Density g/cc	Moisture content %	WHC	pH	EC μ S	Organic matter %	Calcium milli.e qu	Magnesium milli.e qu	Sodium milli.e qu	Potassium mg/ G	Phosphorus mg/G
NA1	1.3823	12.4	9.367	6.296	35.45	4.03	0.45	0.3	0.00275	14.20288	1.64
NA2	1.0965	9.7	12.964	5.987	30.7	4.67	0.4	0.4	0.002	5.3504	1.53
NA3	1.197	15.4	13.68	6.065	61.06	3.29	0.45	0.2	0.00175	19.35872	0.6
NA4	1.3073	17.7	12.63	6.374	53.97	3.89	0.3	0.2	0.002	30.93504	0.8
NA5	1.658705	11.48515	13.2	4.831	24.72	0.67	0.1	0.05	0.00275	5.44768	3.4
NA6	1.360138	21.6	31.93613	6.777	31.01	1.27	0.25	0.2	0.00475	9.33888	0.96
NA7	1.227442	19.15323	29.31727	5.839	77.73	0.53	0.1	0.15	0.002	2.9184	0.831
NA8	1.758227	17.52988	13.77246	6.274	56.5	0.23	0.15	0	0.003	2.72384	0.4
NG1	1.5587	9.3	35.956	6.322	55.06	4.13	0.8	0.25	0.00275	19.456	0.92
NG10	1.094745	21.23016	41.8	6.305	14.55	3.96	0.9	0.2	0.003	24.70912	0.35
NG2	1.133	10.5	30.953	5.487	21.03	2.55	0.2	0.1	0.00175	7.00416	0.76
NG3	1.15	11.7	38.604	5.606	34.3	2.45	0.4	0.1	0.00225	15.75936	0.29

NG4	1.592357	7.056452	28.88446	5.117	18.48	1.44	0.05	0.05	0.00325	4.76672	0.85
NG5	1.426486	15.55118	44.13519	5.846	33.01	3.59	0.35	0.15	0.0025	13.52192	0.8
NG6	1.592357	10.6	19.92032	5.51	22.2	2.75	0.25	0.15	0.00225	17.80224	0.25
NG7	1.29379	9.306931	43.71257	5.676	25.21	2.79	0.3	0.25	0.0025	13.42464	0.9
NG8	1.691879	4.970179	39.84064	5.26	24.21	1.51	0.1	0.2	0.00275	12.16	0.5
NG9	1.592357	20.6	31.26253	5.209	16.05	1.27	0.05	0.05	0.015	3.4048	0.7
YE1	1.1282	16.3	38	6.118	116	5.88	0.8	0.4	0.004	44.65152	0.201
YE2	1.0976	14.3	32.804	6.037	38.33	1.27	0.4	0.4	0.00225	18.9696	0.39
NA1-NA8 = Samples from Nandihol� sub basin, NG 1-10 = Samples from Nagodihol� sub basin, and YE-1 and 2 = Samples from Yennehol� sub basin.											

CONCLUSION

In the present study, the ecological investigations of selected streams and eight tributaries in the Sharavathi river basin, Western Ghats was undertaken. The streams were selected from Nandihol , Nagodihol  and Yennehol  sub-basins of Sharavathi. The eight tributaries of upstream of Sharavathi river basin were selected for the study. The ecological investigations included the land use pattern of the catchment, physico-chemical and biological analysis of water, hydrological assessment and physico-chemical analysis of soil samples. The land use pattern analysis was analysed using remote sensing data. The hydrological assessment included stream flow analysis and rainfall computation. Vegetation analysis of the catchment was done by random transect cum quadrat method to investigate the influence of vegetation on the water quality, soil quality and stream discharge. The analysis of soil and water was done by standard methods. The results of the ecological investigations revealed

- **Land-Use pattern** : Among the eight sub-basins of Sharavathi upstream catchment, Nagodihol  had the maximum evergreen and semi-evergreen forests (52.14%) followed by Hilkunji (43.27%) > Yennehol  (37.89 %) > Hurlihol  (32.78%) > Sharavathi (19.16%)> Mavinhol  (4.37 %) > Nandihol  (3.31 %) > Haridravathi (2.28%). The agricultural lands present in the sub-basins were Haridravathi (18.19%) > Nandihol  (11.33%)> Sharavathi (10.33%) > Mavinhol  (9.81%) > Hilkunji (4.18%) > Hurlihol  (1.97%) > Yennehol  (1.37%) > Nagodi (1.08%). The Land use pattern analysis shows that the forest areas have been replaced with agricultural activities in the sub-basin.

- **Water quality of the Tributaries:** The physico-chemical and biological analysis of the eight tributaries in the Sharavathi upstream catchment showed that all the parameters were within permissible limits. But electrical conductivity, total dissolved solids, turbidity, sodium and potassium values were relatively high in Nandihol , Haridravathi and Mavinhol . The Palmer algal index showed high scores values in Nandihol  indicating organic pollution during the sampling period. This is mainly due to the agricultural activities in the catchment.

- **Micro – level assessment:** The micro-level assessment included the vegetation analysis, water quality, stream discharge and soil quality of selected streams in three sub-basins of Nandihol , Nagodihol  and Yennehol . The results are as follows

- **Vegetation Analysis of the sub-basin:** The vegetation analysis of the stream catchment of the three sub-basins of Nandiholé, Yenneholé and Nagodiholé revealed that Nagodiholé catchment had high endemism, evergreenness and total basal area followed by Yenneholé and Nandiholé. The characteristic feature of an undisturbed forest is high endemism and evergreenness but agricultural and other anthropogenic activities in the Nandiholé have resulted in the loss of endemic and evergreen species.
- **Stream water quality:** The physico-chemical and biological analysis of the water quality revealed that the streams of Nandiholé sub-basin showed high values of TDS, turbidity, electrical conductivity, sodium and potassium values. All the streams in this sub-basin were also faecally contaminated. This is due to the increased anthropogenic pressure in Nandiholé compared to Yenneholé and Nagodiholé.
- **Stream flow:** The streamflow measurement varied radically between the first and second order streams of the three sub basins. The two out of the four streams in Nandiholé dried during the study period (i.e., during January and February of 2004). The other two streams of this sub-basin showed very low discharge values when compared with streams of Nagodiholé and Yenneholé. The results reveal that the stream flow varies according to the topography and rainfall pattern and forest cover in the catchment. The catchment with high forest cover like Nagodiholé and Yenneholé shows a high stream discharge, whereas catchment area with highest agricultural land shows a low stream discharge.
- **Soil quality:** The soil quality analysis revealed that the soil was productive in the Nagodiholé and Yenneholé sub-basins whereas the parameters like low organic content, high bulk density, etc revealed that the soils of Nandiholé sub-basin were degraded.

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Appendix-1

Appendix: 1 complete list of Phytoplankton obtained during study period.			
Serial No	Species name	January	February
1	<i>Achnanthes elata</i> Gandhi	+	
2	<i>Anabaena affinis</i> Lemmarmann	+	+
3	<i>Anabaena spiriodes</i> Kleb		+
4	<i>Ankistrodesmus falcatus</i> var <i>radiatus</i> (Chodut) Lemn		+
5	<i>Ankistrodesmus convolulus</i> Corda	+	+
6	<i>Ankistrodesmus falcatus</i>	+	+
7	<i>Ankistrodesmus falcatus</i> (corda) Ralfs		+
8	<i>Anomoeneis lanceolata</i> Gandhi		
9	<i>Anomoenesis brachysira</i> (Breb) Grun v. tEhrmalis	+	
10	<i>Anomoenesis sphaerophora</i> (Kuetz) P.filter		+
11	<i>Aphancapsa felicitissima</i> Nest & West		+
12	<i>Aphanocapsa delicatissima</i>	+	+
13	<i>Apiocystis brauniana</i> Nargali		+
14	<i>Ceratium hirundinella</i> (O.F.Muell) Dujardin	+	+
15	<i>Ceratoneis arcus</i>		+
16	<i>Chlamydomonas angulosa</i> Dill	+	
17	<i>Chlamydomonas genkowskii</i> schmidle	+	
18	<i>Chlamydomonas globosa</i> . Snow	+	
19	<i>Chlamydomonas polypyrenoideum</i> Prescott		+
20	<i>Chlamydomonas pseudopertyi</i> PascEhr	+	+
21	<i>Characloopsis pyriformis</i> (A.Braun) Borzi		+
22	<i>Chlamydomonas globosa</i>		+
23	<i>Chlamydomonas globosa</i> snowCosmarium marginatum Ray et Biss		+
24	<i>Chlorococcum humicula</i> (Naeg) Rabenhorst	+	+
25	<i>Chlorococcus disperses</i> var. <i>elegans</i> G. M. Smith		+
26	<i>Chlorococcus turgidus</i> (Kuetz) Naegli	+	

27	<i>Chrococcus limneticus</i> var. <i>subsales</i> Lemmermann		+
28	<i>Closteriopsis longissima</i> Lemmermann	+	+
29	<i>Closterium calosporum</i>		+
30	<i>Closterium ehrenbergii</i> Mengh		+
31	<i>Closterium kuetzingii</i> Breb. var. <i>vittatum</i> Nordst	+	+
32	<i>Closterium lunula</i> (Mull) Nitzsch var. <i>massartii</i> (Wilden) Krieg.		+
33	<i>Clostridium ehrenbergii</i> Menega	+	
34	<i>Clostridium geratitum</i> Nordst		+
35	<i>Cocconeis maharashtrensis</i> sp. nov	+	
36	<i>Cocconeis placentula</i>	+	
37	<i>Coelastrum dubium</i> Grunow	+	
38	<i>Coelastrum microporum</i> (Naegeli)	+	+
39	<i>Cosmarium decoratum</i> West & West		+
40	<i>Cosmarium inaculatum</i> Turn	+	
41	<i>Cosmarium lundellii</i>		+
42	<i>Cosmarium marginatum</i> Ray et Bis	+	+
43	<i>Cosmorium nudum</i> (Turn) Gutur	+	
44	<i>Cyclotella calenta</i> Bren	+	+
45	<i>Cylindrospermum major</i>		+
46	<i>Cymbella bengalensis</i> Grun		+
47	<i>Cymbella chandolenis</i>	+	
48	<i>Cymbella cymbiliformis</i>	+	
49	<i>Cymbella cymbiliformis</i> var. <i>caldostagnensis</i> (Meist) A Cl	+	+
50	<i>Cymbella leptoceros</i> Ehr Grun		+
51	<i>Cymbella powaiana</i> Gandhi		+
52	<i>Cymbella tumida</i> (Bren)	+	+
53	<i>Cymbella tumidula</i> Grun	+	
54	<i>Cymbella ventricosa</i>		+
55	<i>Cymbella ventricosa</i> Kuetz		+
56	<i>Dactylococcopsis acicularis</i> Lemmerman	+	
57	<i>Dactylococcopsis raphidioides</i>	+	
58	<i>Desimidium bengalicum</i> Turn	+	+
59	<i>Desimidium quadratum</i> Nordst	+	+
60	<i>Desmidium swartzii</i> Agardh		+

61	<i>Dinobruos divergens Imbof</i>		+
62	<i>Dinobryon sertularia Ehrenberg</i>		+
63	<i>Dinobyron divergens Imhoff</i>	+	+
64	<i>Dinodryon cylindricum</i>		+
65	<i>Diploneis subovalis</i>		+
66	<i>Echinosphaera limnetia G.M .Smith</i>	+	
67	<i>Epithemia soxes Kuetz</i>	+	+
68	<i>Epithemia zebra (Ehr) Kuetz</i>	+	+
69	<i>Eputhema sores Kuetz</i>		+
70	<i>Eremosphaera oocystoides Presscott</i>		+
71	<i>Eudorina elegans Ehrenberg</i>	+	+
72	<i>Eugelena acus Ehrenberg</i>		+
73	<i>Euglena spirogyra (Ehr)</i>		+
74	<i>Eunetia lunaris (Ehr) Grun</i>		+
75	<i>Eunotia alpina (Naeg) Hustedt</i>		+
76	<i>Eunotia hebridica A Berg V.bergii Gandhi</i>	+	+
77	<i>Eunotia lunari (Ehr) Grun</i>	+	+
78	<i>Eunotia lunaris</i>	+	+
79	<i>Eunotia major (W. Smith) Rath.</i>		+
80	<i>Eunotia major (W. Smith) Rath. V. indica (Grun)</i>	+	
81	<i>Eunotia monodan. Ehr</i>	+	
82	<i>Eunotia pectinalis Var undulata (Rarfs)</i>	+	
83	<i>Eunotia praerupta Ehr</i>		+
84	<i>Fragilaria brevistrimayta Grun. v.vidarbhensis v.nov</i>		+
85	<i>Fragilaria construens (Ehr)Grun.V.venter Grun F pusilla Grun</i>	+	+
86	<i>Fragilaria construens (Ehr)Grun.V.venter Grun F pusilla Grun</i>		+
87	<i>Frustulia jogensis Gandhi</i>	+	+
88	<i>Frustulia saxonica Rabh</i>		+
89	<i>Frustulia soxenica Rath f. indica f. nov</i>	+	+
90	<i>Gleotrichis natans (Raben)</i>		+
91	<i>Gloeocapsa magna (Breb) Kutz</i>	+	+
92	<i>Gloeotrichia echinulata (J. E Smith)</i>		+
93	<i>Gloeotrichio natans (Rabew)</i>	+	+

94	<i>Gloetrichia echinulata (J.E.Smith)</i>	+	+
95	<i>Gomphoenma lanceolatum Ehr</i>	+	+
96	<i>Gomphonema attenuatum (Kuetz) Rabh</i>		+
97	<i>Gomphonema augar Ehr</i>	+	+
98	<i>Gomphonema gracile Ehr</i>		+
99	<i>Gomphonema gracile Ehr V.intricatiforme Meyer</i>	+	
100	<i>Gomphonema gracile Ehr V.Subcapitata Gandhi</i>	+	
101	<i>Gomphonema intricatum Kuetz</i>	+	+
102	<i>Gomphonema lanceolatum Ehr</i>	+	+
103	<i>Gomphonema lanceolatum var insigus (Gerg) Cleve</i>		+
104	<i>Gomphonema lanceollatum Ehr</i>		+
105	<i>Gomphonema lingulatum Hustedt</i>		+
106	<i>Gomphonema longiceps Ehr.v.subclavats Grun</i>	+	+
107	<i>Gomphonema olivaceoides Hustedt</i>	+	
108	<i>Gomphonema sumatrense Frickle</i>	+	+
109	<i>Gomphonera longiceps Ehr v.subclavata Grun.</i>	+	
110	<i>Gomphosphaeria aponina Kuetz</i>	+	
111	<i>Gomponema augus Ehr</i>	+	
112	<i>Gomponema gracile Ehr</i>		+
113	<i>Goniochloris sculpta Geitter</i>	+	+
114	<i>Gonium sociale (Dly)</i>		+
115	<i>Gonium sociale (Duj) warming</i>	+	+
116	<i>Gyrosigma bhusavalensis sp nov</i>	+	+
117	<i>Haematococcus lacustris (Girod) Rostaf</i>		+
118	<i>Haemotococcus lacustris (Girod)</i>	+	
119	<i>Hantzschia amphioxys (Ehr) Grun v.recta O.Muell f.typica A.Cl</i>	+	+
120	<i>Hantzschia voigtii Gandhi</i>	+	
121	<i>Ichthyocerus longispinus. Var .pororhium</i>	+	
122	<i>Kirchnerilla obesa (W.West) Schmidle</i>	+	
123	<i>Lepocinclis fusiformis (Carter) Lemmerma</i>	+	
124	<i>Mastoglia amoyensis Voigt v.robusta Gonzalves et Gandhi</i>	+	+
125	<i>Mastoglia exigua Lewis f brevirostris Venkat</i>	+	+
126	<i>Mastogloia amoyens</i>		+
127	<i>Mastogloia dolosa Venkat V.ambigua Gonzalves et Gandhi</i>	+	+

128	<i>Mastoloia exigua</i> Lewis F. <i>brevirestris</i> Venkat		+
129	<i>Melosira granulata</i> (Ehr) Ralfs	+	+
130	<i>Melosira granulata</i> (Ehr) Ralfs v. <i>angustissima</i> O. Muell	+	
131	<i>Micractinium pusillum</i> var <i>elegans</i> G.M. Smith	+	+
132	<i>Micractinium quadrisetum</i> (Lemn) G.N. Smith	+	+
133	<i>Micrasterias foliacea</i> Bail var <i>quadrinflata</i> var <i>nov</i>	+	
134	<i>Micrasterias torreyi</i> Bail var <i>Curvata</i> Krieg. Fa	+	+
135	<i>Microcystis aeuginosa</i> Kuetz emend Elenkin		+
136	<i>Navicula cari</i> Ehr	+	+
137	<i>Navicula cuspidata</i>	+	+
138	<i>Navicula cuspidata</i> Kuetz	+	+
139	<i>Navicula cuspidata</i> Kuetz V. Major Meister f. <i>robusta</i> Gonzalves et Gandhi	+	
140	<i>Navicula cuspidata</i> Kuetz f. <i>brevirostrata</i>	+	+
141	<i>Navicula gracilis</i> Ehr	+	
142	<i>Navicula gregari</i> Donk	+	+
143	<i>Navicula microcephala</i> Grun	+	
144	<i>Navicula microcephala</i> Grun	+	+
145	<i>Navicula munuta</i> (Cleve) A. Cl	+	
146	<i>Navicula mutica</i>	+	+
147	<i>Navicula mutica</i> Kuetz		+
148	<i>Navicula pupula</i> Kuetz v. <i>rectangularis</i> (Greg) Grun		+
149	<i>Navicula pygmaea</i> Kuetz V. <i>indica</i> skn		+
150	<i>Navicula radiosa</i> Kuetz	+	+
151	<i>Navicula radiosa</i> Kuetz V. <i>tenella</i> (Breh. ex. Kuetz) Grun		+
152	<i>Navicula reinhardtii</i> Grun. F. <i>gracilior</i> Grun	+	+
153	<i>Navicula venezuelensis</i> Hustedt	+	+
154	<i>Navicula rhychocephala</i> Kuetz V. <i>grunowii</i> A. Cl		+
155	<i>Navicula rhynchcephala</i> Kuetz <i>velongava</i> Mayer	+	+
156	<i>Navicula rhynchocephala</i> Kuetz		+
157	<i>Navicula rhynchocephala</i> Kuetz. V. <i>elongata</i> Meyer	+	
158	<i>Navicula rhynchocephala</i>		+
159	<i>Navicula venezuelensis</i> Hustedt	+	+
160	<i>Navicula viridula</i> Kuetz	+	
161	<i>Neidium amphiohynchus</i> (Ehr) Pfitzer V. <i>medium</i> A. Cl		+

162	<i>Neidium dubium</i> (Ehr) Cleve v. <i>cuneatum</i> Font		+
163	<i>Neidium marathwadensis</i> sp. nov	+	+
164	<i>Nitzschia obtusa</i> W. Smith	+	
165	<i>Nitzschia apiculata</i> (Greg.) Grun	+	
166	<i>Nitzschia closterium</i> . W. Smith	+	+
167	<i>Nitzschia jugata</i> Gandhi	+	
168	<i>Nitzschia kuetzingiana</i> Hilse	+	+
169	<i>Nitzschia maharashtrensis</i> sp. Nov	+	
170	<i>Nitzschia obtusa</i> W. Smith	+	+
171	<i>Nitzschia palea</i>	+	
172	<i>Nitzschia sublinearis</i> Hustedt	+	+
173	<i>Nostac sphaerium</i> VacEhr		+
174	<i>Oedogonium angustum</i> .Tiffany	+	
175	<i>Oedogonium anomalum</i> Hirn	+	
176	<i>Oedogonium oviforme</i> fragrace Prescott		+
177	<i>Oedogonium patulam</i> Tiffany		+
178	<i>Oedogonium pyriforme</i>	+	
179	<i>Oocystis giagas</i> ArcEhr	+	+
180	<i>Oocystis nodulosa</i> West & West		+
181	<i>Oscillatoria acutissima</i> Kufferath	+	+
182	<i>Palmodictyon viride</i> Kuetzing		+
183	<i>Pandorina morum</i> (Muell.) Bory	+	+
184	<i>Pediastrum boryanum</i> (Turp) Meneghini	+	
185	<i>Pediastrum simplex</i> Meyer	+	+
186	<i>Periumm spirostriolatum</i> Barker		+
187	<i>Phacus acuminatus</i>		+
188	<i>Phacus orbicularis</i> Huebhei	+	
189	<i>Phacus tortus</i> (Lemn) skorrtzov		+
190	<i>Phaeothamnion confervicola</i> LagerEhrm	+	+
191	<i>Pinnularia acrosphaeria</i> (Breb) W. Smith V. <i>Sanducensis</i> A.S		
192	<i>Pinnularia borealis</i> Ehr	+	
193	<i>Pinnularia braunii</i> (Grun) Cleve		+
194	<i>Pinnularia brebissonil</i> (Kuetz) Cleve . V. <i>hybrida</i> (Grun) A. Cl	+	+
195	<i>Pinnularia brevicostata</i> Cleve V. <i>indica</i> Gandhi		+
196	<i>Pinnularia divergens</i> W. Smith. V. <i>capitata</i> Mills	+	+

197	<i>Pinnularia kolhapurensis</i> Gandhi	+	
198	<i>Pinnularia legumen</i> Ehr. v. <i>florentina</i> (Grun) cleve		+
199	<i>Pinnularia maharasterensis</i> Sp.nov		
200	<i>Pinnularia notala</i> (Perag.et Ehr) A.Cl.V	+	+
201	<i>Pinnularia viridis</i> (Nitz) Ehr		+
202	<i>Pinularia borealis</i>	+	
203	<i>Pinularia meisteri</i> A.Cl.v . <i>scandica</i> A.Cl		+
204	<i>Pleurosigma hippocampus</i>	+	
205	<i>Pleurosigma hippocampus</i> W.Sm	+	+
206	<i>Pleurotaenium elatum</i> (Turn)	+	
207	<i>Pyramimonas tetrarhynchus</i> Schmarda	+	+
208	<i>Rapholodia gibba</i> Ehr O Muell		+
209	<i>Rhabdoderma sigmoidea</i> . Fa. Minor	+	+
210	<i>Rhopalodia gibba</i> Ehr. O. Muell	+	+
211	<i>Rivularia aquatica</i> De.Wilde	+	+
212	<i>Scenedesmus abundus</i> (Kirch) Chodat		+
213	<i>Scenedesmus bernardii</i> G.M Smith	+	
214	<i>Scenedesmus dimorphous</i> (Turp) Knetz	+	+
215	<i>Scenedesmus dimorphus</i>	+	
216	<i>Scenedesmus dimorphus</i> (Turp) Lagerheim	+	+
217	<i>Schizothrix friessi</i> Gomont	+	+
218	<i>Schroederia setigera</i> (Schroed), Lemmermann	+	+
219	<i>Spirogyra condensata</i>	+	
220	<i>Spirogyra mirabilis</i> (Hass) Kuetzing	+	
221	<i>Spirogyra poticalis</i> (Muell). Cleve		+
222	<i>Spirogyra subsalsa</i> Kuetzing	+	
223	<i>Spirogyra webri</i> Kuetzing		+
224	<i>Srirogyra scrobiculatia</i> (Stock) Czurde	+	+
225	<i>Starasturam tauphorum</i> West & West		+
226	<i>Staurationum anceps</i>	+	+
227	<i>Staurationum freemanii</i> West and West var. <i>nudiceps</i> Scott and Presc		+
228	<i>Staurationum phoenicenteron</i> Ehr vintermedia	+	
229	<i>Staurationum prionotus</i> sp.nov		+
230	<i>Staurationum protectum</i> West and West var <i>rangoonensa</i> (	+	+

	<i>Skuja)</i>		
231	<i>Staurastrum subuecium sp nov.</i>	+	+
232	<i>Staurastrum thienemanni Kuetz.f.a.triradiatum fa.nov</i>		+
233	<i>Stauroneis anceps Ehr</i>	+	+
234	<i>Stauroneis anceps Ehr f gracilis (Ehr) Cleve</i>		+
235	<i>Stauroneis angulari Gonzales et Gandhi</i>	+	
236	<i>Stauroneis phoenicenteron Ehr f. capitata Gonzalves et Gandhi</i>		+
237	<i>Stauroneis phoenicenteron Ehr V.intermedia(Dippel)</i>	+	+
238	<i>Stigeocctonium flagelliferum Kuetzing</i>	+	
239	<i>Surendra linearis</i>		+
240	<i>Surirella robusta</i>	+	
241	<i>Surivella robustia Ehr</i>		+
242	<i>Synechocystis crassa</i>	+	
243	<i>Synedra acus Kuetz</i>	+	+
244	<i>Synedra acus Kuetz vacula (Kueeetz) V.H</i>	+	+
245	<i>Synedra acus Kuetz.V.acuta (Kuetz).V.H</i>	+	+
246	<i>Synedra minuscula Grun</i>	+	+
247	<i>Synedra tabulata (Ag) Kuetz</i>	+	+
248	<i>Synedra ulna</i>	+	+
249	<i>Synedra ulna (Nitz) Ehr</i>	+	+
250	<i>Synedra ulna (Nitz) Ehr V. danica (Kuetz) Grun</i>	+	+
251	<i>Synedra ulna (Nitz) Ehr v. s pathulifera Grun</i>	+	+
252	<i>Synedra ulna (Nitz) Ehr V.notata Kuetz</i>	+	+
253	<i>Synedra ulna var danica</i>	+	+
254	<i>Synedra ulna. Var.danica (Kuetz) Grun</i>	+	+
255	<i>Synedre acus Kuetz</i>	+	+
256	<i>Tetmemorus gracile Bail.var. undulatum Scott & Presc Desi</i>	+	+
257	<i>Tetrademus wisconsinenese G.M.Smith</i>		+
258	<i>Tetraedron arthrodesimiforme (W.West) Wolszynska</i>	+	
259	<i>Tetraedron hastatum (Reinsen) Hansgrig</i>		+
260	<i>Tetraedron tribobulatum (Reinseh)</i>	+	+
261	<i>Tolypella intricata Leonhardi</i>		+
262	<i>Trachelomonas bulla (Stein) Deflendre</i>	+	+
263	<i>Trachelomonas grardiana (Playf) Deflanare</i>	+	+

264	<i>Trachelomonas hispida</i>	+	
265	<i>Trachelomonas hispida</i> var <i>punctata</i> Lemmermann		+
266	<i>Trachelomonas rotunda</i> Swirenko	+	+
267	<i>Trachelomonas superba</i> var <i>duplex</i> Deflendre	+	
268	<i>Trachelomoncus chookoweinsis</i> Swsirenko		+
269	<i>Trichelomonas borrida</i> Palmer	+	
270	<i>Triplocerus gracile</i> .Bail.var. <i>undulatum</i> Scott & Presc	+	
271	<i>Ulothrix aequalis</i> Kuetzing	+	+
272	<i>Volvox tertius</i> A. Meyer	+	+
273	<i>Westella botryoides</i> (W. West) de Wildermann	+	+
274	<i>Wollea saccata</i> (Wolle) Bornet and Flahault	+	+
275	<i>Xanthidium antilopaeum</i>		+
276	<i>Zoochlorella conductrix</i> Brandt		+

Appendix: 2. List of tree species obtained during the vegetation study.			
Serial. No	Species	Western Ghats endemics	Evergreen species
1	<i>Acacia concinna</i>		
2	<i>Actinodaphne hookeri</i>	+	
3	<i>Adina cordifolia</i>		
4	<i>Aglaia anamallayana</i>	+	
5	<i>Aglaia lawii</i>	+	
6	<i>Alstonia scholaris</i>		
7	<i>Anogeissus latifolia</i>		
8	<i>Antidesma menasu</i>	+	
9	<i>Aporosa lindleyana</i>		+
10	<i>Artocarpus hirsutus</i>	+	+
11	<i>Beilschmiedia fagifolia</i>		
12	<i>Bischofia javanica</i>		
13	<i>Butea monosperma</i>		
14	<i>Callicarpa wallichiana</i>	+	
15	<i>Calycopteris floribunda</i>		

16	<i>Callicarpa tomentosa</i>	+	
17	<i>Canarium strictum</i>	+	+
18	<i>Careya arborea</i>		
19	<i>Cassine glauca</i>		
20	<i>Celtis cinnomomea</i>		
21	<i>Cinnamomum macrocarpum</i>	+	+
22	<i>Cyclostemon confertiflorus</i>	+	+
23	<i>Dalbergia latifolia</i>		
24	<i>Dillenia pentagyna</i>		
25	<i>Dimocarpus longan</i>		
26	<i>Diospyros candolleana</i>	+	
27	<i>Diospyros montana</i>		
28	<i>Dysoxylum binectariferum</i>		
29	<i>Elaeocarpus tuberculatus</i>		
30	<i>Ervatamia heyneana</i>	+	
31	<i>Euonymus indicus</i>	+	+
32	<i>Ficus nervosa</i>		
33	<i>Flacourtia montana</i>	+	
34	<i>Garcinia cambogia</i>		
35	<i>Garcinia morella</i>		
36	<i>Garcinia talbotii</i>	+	
37	<i>Gnetum ula</i>		
38	<i>Harpullia imbricata</i>		+
39	<i>Holigarna arnotiana</i>		+
40	<i>Holigarna beddomei</i>		+
41	<i>Holigarna ferruginea</i>	+	
42	<i>Holigarna grahamii</i>	+	
43	<i>Hydnocarpus laurifolia</i>	+	
44	<i>Ixora parviflora</i>		
45	<i>Knema attenuata</i>	+	
46	<i>Lagerstroemia microcarapa</i>	+	
47	<i>Linociera malabarica</i>	+	
48	<i>Litsea wightiana</i>	+	
49	<i>Lophopetalum wightianum</i>		
50	<i>Macaranga peltata</i>		

51	<i>Mangifera indica</i>		+
52	<i>Mastixia arborea</i>	+	
53	<i>Memecylon umbellatum</i>	+	
54	<i>Mimusops elangi</i>		+
55	<i>Mitraphora heyniana</i>		
56	<i>Murraya paniculata</i>		
57	<i>Myristica dactyloides</i>		
58	<i>Myristica malbarica</i>	+	+
59	<i>Nothopegia colebrookeana</i>	+	
60	<i>Odina wodier</i>		
61	<i>Olea dioica</i>		+
62	<i>Poeciloneuron indicum</i>	+	+
63	<i>Polyalthia fragrans</i>	+	
64	<i>Pongamia pinnata</i>		+
65	<i>Pterocarpus marsupium</i>		
66	<i>Pterospermum diversifolium</i>		
67	<i>Randia dumetorum</i>		
68	<i>Salmalia insignis</i>		
69	<i>Sapindus laurifolia</i>		
70	<i>Saraca asoca</i>		
71	<i>Schleichera oleosa</i>		
72	<i>Symplocos beddomei</i>	+	
73	<i>Syzygium cumini</i>		
74	<i>Syzygium laetum</i>	+	
75	<i>Terminalia bellarica</i>		
76	<i>Terminalia paniculata</i>	+	
77	<i>Terminalia tomentosa</i>		
78	<i>Trema orientalis</i>		+
79	<i>Trewia nudiflora</i>		
80	<i>Vanguria spinosa</i>		
81	<i>Vantilago madraspatana</i>		
82	<i>Vepris bilocularis</i>	+	
83	<i>Xylia xylocarpa</i>		

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