Karnataka Biodiversity Board, Govt. of Karnataka

Final Project Report

Floristic Diversity, Ecological Uniqueness & Conservation Strategies of Riparian Flora of *Netravati* River System in *Western Ghats* Range of *Dakshina Kannada*

Submitted to

Karnataka Biodiversity Board
Ground Floor / 'Vanavikasa' Building
18th Cross/ Malleshwaram
Banglaore-03

Submitted by

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January 2017

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'Floristic Diversity, Ecological Uniqueness & Conservation Strategies of Riparian Flora of *Netravati* River system in *Western Ghats* Range of *Dakshina Kannada'*

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(Project Period: December 2010 to December 2011)

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The final research project report

Chapter 1.

Project Summary

1	**Title**	Floristic diversity, ecological uniqueness & conservation strategies of Riparian flora of *Netravati* river system in *Western Ghats* range of *Dakshina Kannada'*
2	**Project funded by**	**Karnataka Biodiversity Board** Ground Floor / 'Vanavikasa' Building 18th Cross Malleswaram Banglaore-03
3	**Project implement by*:***	**Dr. Keshava H. Korse** Centre for Conservation Biology & Sustainable Development –CCBSD (M.E.R.D.Trust -MERDT ®) *Inchara* / New Patel Sawmill Road Kelagina Guddadamane Sirsi-581402. Ph: 9448931142 E-mail: directorccbsd@gmail.com
4	**Project Period**	December 2010 to December 2011
5	**Major Outcome**	• Identification of major / principle riparian angiosperm plant species in streams of *Netravat*i river valley and their threat analysis. • Identification of rare, endangered threatened (RET) and endemic plant species in these unique tropical forest ecosystems. • Overview of distribution of pteridophytes and bryophytes. • Standardizing strategies for conservation riparian habitats and their flora in the central *Western Ghats* region of Karnataka.

Chapter 2.

Introduction

Various kinds of studies are being done today across the globe for identifying new plant species and understanding the diversity that exists within species level. And, efforts are also being put assess the threat level they are facing due to various reasons. These kinds of studies are considered to be a significant today, since they provide key information for planning and executing right conservation strategies.

Floristic and ecological studies in the ecosystems with rich biodiversity like evergreen forest ecosystems assume further importance as they are crucial for providing natural resource, as well as ecosystem services. It is further important in developing countries of the tropical region like India, because majority of the population directly depend on such natural resources for their livelihood. Therefore, conservation biology based field research is considered to be one of the important conservation approaches and their contributions towards the management of natural habitats are being recognized across the globe. Such research driven inputs would be vital for ensuring the protection of the key habitats and keystone species for the sustainability of the biosphere itself (*Swaminathan, M.S., 2002*).

The tropical evergreen forest ecosystems are increasingly brought under focus and efforts are being made to understand the huge life forms they support across the globe. These primary climax ecosystems show high endemism of flora, fauna and microbe, having unique structures, functions and relatively high productivity. Evergreen forest regions of India especially in *Eastern Himalaya* and *Western Ghats* are recognized to be such huge biodiversity points, as they represent the biodiversity hotspots of global significance. (*Myers et al. 2002*). *Western Ghats* alone, for instance, has nearly more than 4800 species of recorded flowering plant species; nearly 2100 species among them are considered to be endemic (*Ramesh, B.R. & Pascal, J.P., 1996).* The ecological uniqueness

of *Western Ghats* is the function of different factors namely, its origin, geological past, climate, impact of monsoon and anthropological activities and so on (*Radahakrishna, B.P., 1993*). High species diversity seen here is, thus, also attributed diverse ecosystems evolved here like shola forest, grassland regions, valley systems, marshy lands, different gradients in the light penetration in forest ecosystems, niche habitats like riverbeds, forest canopy, stream banks etc. Riparian ecosystem is one such vital component of *Western Ghats*, which has unique ecological characters in terms of their structure and functions.

Riparian zones are niche habitats, where interface of water and land is seen. They are considered to be performing many vital functions like regulating water cycle of the forest floor, nutrient cycles of the lower command area, acting as breeding sites for many sensitive organisms etc. These ecosystems are now being widely studied across the tropical region due to their increasingly evident significance (*Subramanian, K., 2005*, *Jaffer et. Al*., 2002 and *Maso-aki et al.,* 1997). Because of that unique physico-chemical and biological properties, they are found to be contributing much to the biodiversity of the *Western Ghats* too, especially the floristic one (*Puri, G.S.* 1983). However, they continue to get destroyed due to various anthropogenic pressures like encroachment, fragmentation, unsustainable harvesting, riverbed sand mining, urbanization and developmental projects of various nature and scale. Therefore, it is high time to look into these ecological niches for understanding their status and also to design effective conservation strategies.

This research project has attempted to study riparian ecosystem and its floristic composition in the *Netravati r*iver valley system in the foothills of central *Western Ghats* in *Dakshina Kannada* (12^0 $29^{'}$ $36^{"}$ to 13^0 $49^{'}$ $22^{"}$ **N** and 74^0 $37^{'}$ $24^{"}$ to 75^0 $41^{'}$ $00^{"}$ E) district of Karnataka (Gazette of D.K.). The taxonomical and ecological studies in these regions were carried out during the period of almost 14 months from October 2010 to December 2011. Later, based on the recommendations of expert committee of Karnataka Biodiversity Board, some studies are done again in the period of 2014 to 2016. Thus,

efforts are made to assess the floristic composition of these riparian ecosystems and also the ecological uniqueness of their structure and functions, seasonal dynamics, threats of various kinds and role of local communities in the management of these ecosystems. By doing such in-depth analysis, an effort is made to develop a field based conservation solutions.

Mainly, the taxonomical investigations are carried out in major streams of *Netravati* river system in *Belthangady* taluk. It has basically tried to understand principle angiosperm species diversity, species abundance, relative dominance of species, population density etc. in riparian zones. The ecological studies focus on physico-chemical analysis of water and soil samples from the riparian zones and the role of vegetation in river bank ecology. Finally, investigations are also made on the vital relationship between these forest ecosystem and local communities, the dynamics of socio-economic backgrounds of the local communities and their implications of the nearby forest management, kinds and degree of anthropogenic pressures etc. All these efforts have lead to generate a few specific suggestions. They could be adopted as conservation strategies both by govt. departments and civil organizations.

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Chapter 3.

Research Objectives

The *Western Ghats* region of peninsular India has been recognized as one of the important ecological regions in the entire world, because of its unique geographical structure, biological diversity and ecosystem services it is offering. This mountain hilly region is considered to be very much vital for the water security of the peninsular India, as most of the river systems of south India take origin in the pristine evergreen forest of these hills. Therefore, studies for understanding these ecosystems and designing conservation strategies assume much significance for the very protection of *Western Ghats* ecosystems

The riparian zones are one of those vital ecosystems of the *Western Ghats* regions having the unique structural and functional properties. They are the ecological niches along the perennial rivers, where water zone meets the land and thereby creates a different habitat. These riparian zones are, therefore, being studied from different perspectives due to their unique properties. Here an attempt is made to do ecological studies on such riparian zones along the perennial river systems of central *Western Ghats* region. The emphasis of this study is mainly on the riparian flora found in those regions and their ecological significance in the *Netravati* river valley, which is a major west flowing perennial river in the central *Western Ghats* region of Karnataka. The objectives are summarized below:

- To understand the basic geographical design of the rivers and the modes of branching pattern in terms of orders.
- To understand the expanse of riparian zones as niche ecosystem and to develop simple guidelines for demarcating them for the purpose of executing conservation actions.

- To understand the physico-chemical properties and their uniqueness and seasonal dynamics.
- To asses the floristic composition of the upper reaches of *Netravti* river valley and understand their uniqueness
- To identify the riparian flora of river *Netravati* and their distribution pattern.
- To understand the ecological functions of the rivers and their influence downstream ecosystem.
- To asses the current scenario of ecological health of the riparian zones.
- To develop conservation strategies for protecting riparian zones and conserve ecologically sensitive riparian plant species.

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Chapter 4.

Research Methodology

This particular study is done on unique ecological niche habitats in the perennial streams of upper *Netravati* River valley system in the central *Western Ghats* range in *Dakshina Kannada* district in Karnataka. The methodologies adopted in this study are:

I. Taxonomic studies:

Field studies are made to assess the distribution of Angiosperm, Pteridophytes & Bryophyttes flora in riparian zones. The special emphasis was given on the phenology and reproduction biology of woody angiosperms, which are mainly found in riparian zones. Besides, an assessment is also made on thereat levels of those woody riparian plant species (Rare, endangered, threatened & endemic levels).

This floristic study was done by adopting standard taxonomic filed survey methods as below:

- Five Quadrats of 10M X 10M were laid in a Transect of 500 M.
- Every major stream was sampled by laying six such Transects were laid right angle to the stream flow direction, starting from the centre of the river bed towards the bank region.
- Totally 10 such major streams are studied, selected from I-order, II-order & III-order equally. The stream structure and classifications is graphically represented in Fig.1 and sampling methods are illustrated in Fig.2, given at the end of this chapter.

II. Ecological Studies:

The key features of these riparian habitats of first to third order streams, in terms of general soil & aquatic characters, physiognomy, general biodiversity (apart from woody plants) are studied by following methods:

a). Physico-chemical properties of Soil & water : The periodic samples were taken to study soil quality in riverbed & river bank and water quality in streams. Primary parameters like temperature, turbidity, pH, total suspended particulate matter in water samples and sticky nature, moisture percentage, total organic content, and the proportion of sand in the soil samples were tested. They were assed by adopting appropriate standard methods (*APHA*, 1985).

b). Ecology of the habitat: The ecological features were studied by documenting all visible details in many points, apart from the quadrat sampling locations. They include observing and recording physiognomy, canopy opening pattern, atmosphere temperature, biodiversity other than non-woody plant species etc.

III. Threat Analysis:

The riparian ecosystems are facing multiple threats, which are responsible for the irreversible damage of these fragile habitats. They were assessed by adopting multiple methodologies like field investigations, interacting with various stakeholders like local people, farmers, tribal, and forest dwellers and cross checking the documents available with the *Taluka* level line departments like dept. of forest and dept. of revenue.

IV. Developing both *in-situ* & *ex-situ* conservation strategies:

Strategies for conservation of riparian biodiversity with special emphasis on RET & Endemic woody flora are developed by combining Conservation Biology principles with that of opinion of all the stakeholders.

V. Policy Advocacy:

Efforts are done to suggest concrete interventions both for policy and the programmes, aiming at conservation of these habitats and biodiversity with suitable policy frameworks, schemes and guidelines by involving all concerned departments, especially the dept. of forest, dept of environment and *Panchayat Raj* institutions.

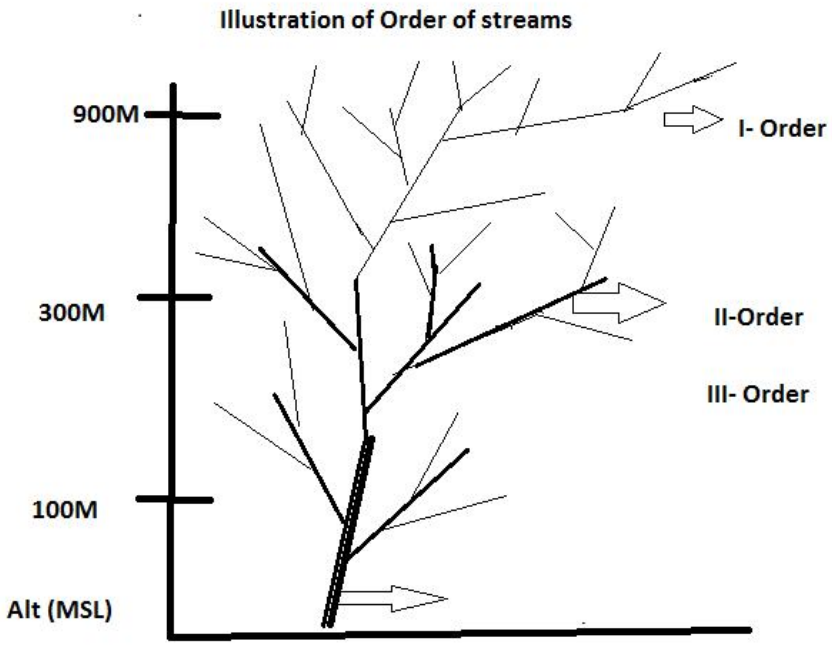

Fig.1. Illustration of stream flow pattern
(with their classification and expanse with respect to the altitude)

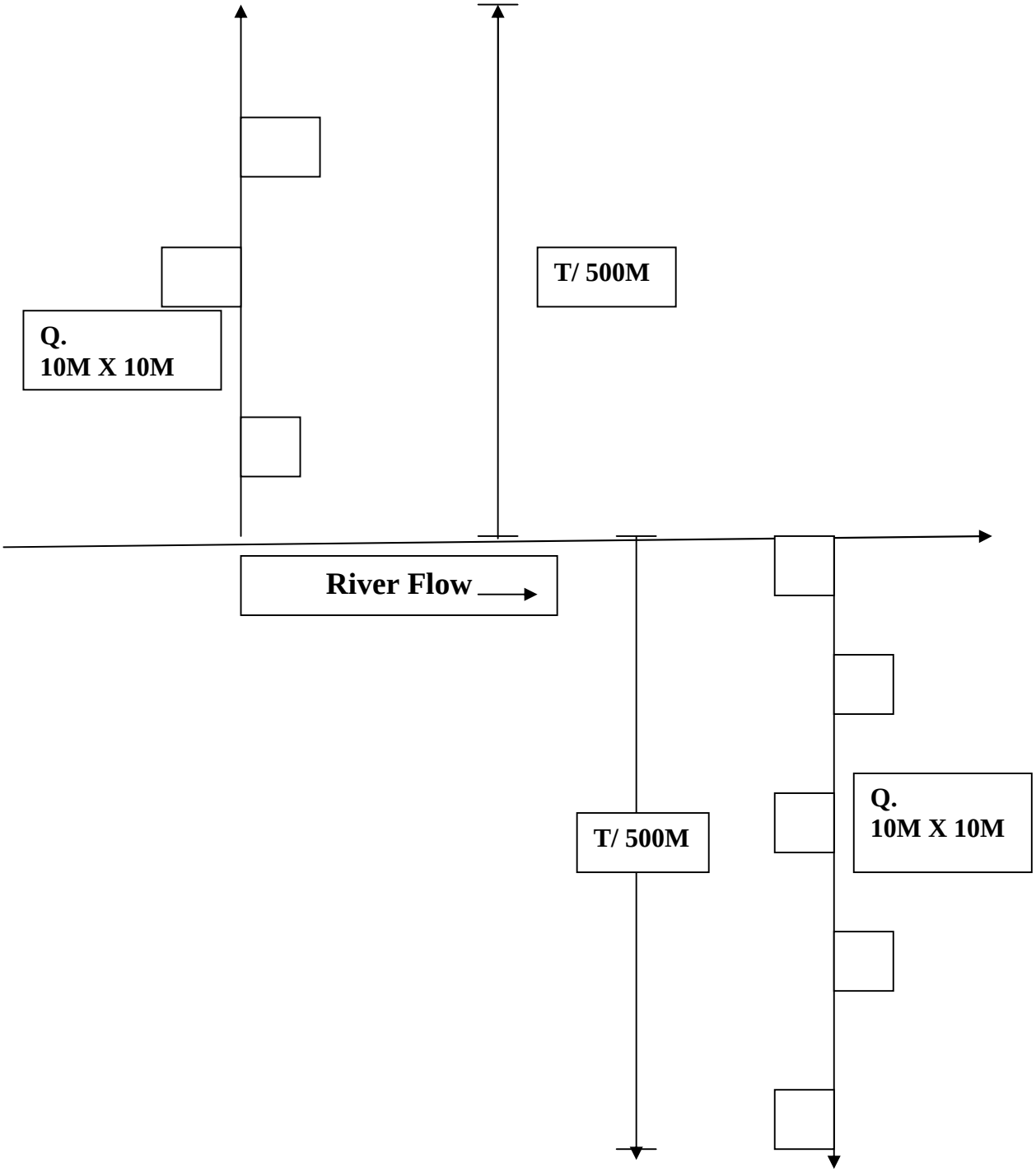

Fig. 2. The scheme showing sampling method design
(Patterns of Transects & Quadrats laid).

Chapter 5.

Significance of the study region

This filed based Conservation Biology research work is carried out in the *Charmady* and *Shishila* Reserve Forest range in the north–east part of *Bethangady* taluk of *Dakshina Kannada* district in Karnataka. It is principal catchment area of *Netravati* River, having evergreen forest ecosystem in the altitude range of 50 to1200 MSL. The study mainly comprised the I-order, II-order & III- order perennial streams in this foothill range of central Western *Ghats* region. The major perennial stream systems in which this study is carried out are *Mundaje* River & *Shishila* Rivers, both the principal tributaries of River *Netravati.*

Reasons for the site selection:

1. The ***Charmady*** forest region is one of the less disturbed evergreen forest ecosystems in the central *Western Ghats* range in Karnataka.
2. It is the principal and primary catchment area of River ***Neravati,*** which feeds the entire ***Dakshina Kannada*** district. This river is remained perennial only because of this relatively well protected *Charmady* catchment area.
3. It is having very pristine & original primary evergreen forest, which is very much vital for the River *Netravati* in terms of watershed and other ecological services values.
4. It is a region having crucial elephant corridor between ***Kuduremukh*** **National Park &** ***Pushpagiri*** **Wildlife Sanctuary** via ***Gudya River*** valley. Therefore, any conservation effort of this evergreen Reserve Forest region would considerably enhance the ecosystem quality in both these Protected Areas.
5. Nearly 10 major perennial streams of ***Mundaje*** **&** ***Shishila*** Rivers are studied here, which are major tributaries of River *Netravati.*

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Chapter 6.
Results & Discussions

Before taking up the research work, extensive literature study was done on aspects aspects like forest ecology, *Western Ghats* ecology, hydrology etc. The geo-morphology & geological uniqueness of central *Western Ghats* region and its role in watershed services in the region were also look into. The research methodology comprising taxonomy study methods, water and soil analysis techniques etc. were also reviewed. Various reference books, journals, back volumes of the peer reviewed / referred journals from the libraries of SDMC, Ujire, Mangalore University library, Fisheries College Mangalore, Indian Institute of Science Bangalore (IISc), ATREE Bangalore, Bangalore Agriculture Universality, Institute for Socio- Economic Change (ISEC) Bangalore etc. were referred. Based on all these literature review the final research methodology was designed. The key components of methodology adopted were:

1. The initial exploratory filed survey was conducted in the *Netravati* river valley in *Belthangady* taluk of *Dakshna Kannada* for finalizing the sampling sites for soil, water and vegetation studies.
2. Floristic studies in the samples taken on the river bed, river bank as well as the adjoining catchment area to prepare the check list of the plant species in evergreen forest by laying Transects and Quadrats. Totally 10 perennial streams were studied by laying 6 transects in each stream and 5 Quadrants in each transect. Therefore, the taxonomic study is done by taking total 05 X 06 X 10=300 Quadrants, which adequately represent this niche ecosystem.
3. Soil and water samples collection were made for two seasons in 20 different locations, taking samples at two sites for each stream, for all 10 steams studied.
4. Inventory of riparian flora was done with a special attention woody Angiosperms species, along with studies on their ecological uniqueness and significance like

IUCN Red list categories. Besides that, major Pteridophytes and Bryophytes were also recorded.

5. Ecological studies on the types and status of vegetations in selected sampling sites were recorded.
6. Periodic measurements of water flow in the selected streams were also recorded.

Thus, all the primary objectives of the study are fulfilled. The ecosystem restoration practices are finally suggested based on the empirical data. All those findings are summarized further.

The key findings:

1. The floristic composition of upper reaches of riparian zones of *Netravati* River:

A. Angiosperms:

The riparian zone of this perennial river system of *Netravat*i valley is found to be very much rich in terms of floristic diversity. More than eighty Angiosperm tree species and ten shrub species are recorded in all 10 different streams studied. Nearly 20 species among them are found to be belonging to IUCN Red list categories and Endemic groups. They are all given in the **Table-1.** The images of some of those species are given Plate section.

The streams studied in the slope gradient from 50 to1200 MSL. The overall diversity of woody plant species finds its peak at around 200 to 400 MSL altitude. As we go further up from those elevations, woody plant diversity starts decreasing. However, this does not account for the other life forms like seasonal herbaceous flora like grasses, that are visible in monsoon season or spatially distinct flora like canopy orchids.

Riparian woody plant species of Angiosperm:

The taxonomical field investigations have revealed that there are at least 14 exclusive riparian woody plant species in this region. They are all listed in **Table-2**. The images of some of those species are given Plate section.

The most abundant tree species found along the stream edges are *Ochlandra travacoria,* the woody shrub and *Holigarna arnotiana* Hook, the tall trees. The *Cinnamomum ripaium* is most rare species with very limited distribution. The stream bed region is rich in the shrub species like *Homonoia riparia,* and herb *Rotula aquatic. Ochlandra travacoria* species are found only in this ecological zone indicating the significance of these micro-habitats.

Most of the riparian plant species recorded here are found to be in IUCN Red list categories. They are species like *Madhuca nerifoila* H.J.Lam., *Holigarna arnotiana* Hook., *Holigarna grahmii* Kurz., *Ochreinauclea missionis* Ried., *Actinodaphne bourdillonii* Gamble., *Ochlandra scriptoria* Fischer., *Neolamarkia cadamba* Roxb., *Callophyllum inophullum* L., etc.

B. Distribution of Bryophytes and Pteridophytes:

The primary objective of this research project was to identity the riparian angiosperm species, which are highly unique and vulnerable to different ecological and anthropogenic pressures. However, an effort was also made to asses the diversity and distribution of Bryophytes and Pteridophytes in the study area. They assume significance on two counts. One, this *Western Ghats* terrain harbors the huge diversity of lower plant groups like higher Thallophyta and lower Trachaeophyta. Two, they are also the indicators of the ecological health, since they are sensitive to the short term changes in climate and edaphic characters.

Two types of samples were taken for Bryophytes and Pteridophytes.

1. Samples collected during Quadrat studies.
2. Random samplings at more potential habitats like riverbed, river bank rocks, tree trunks on the higher elevations etc. for Bryophytes and river bank edges, the gorges, the grass lands of high elevation etc. for Pteridophytes.

These samples were taken to the laboratory for their identification by using standard floristic keys based on the structure of reproductive bodies and leaves.

This study indicates that this area is highly diverse in these forms of plants as well. In order to have get detailed account on their diversity, further in depth studies are necessary. The findings of these studies are given briefly here.

A. Bryophytes:

Plants belonging to all three principle groups are found They are: Liverworts (*Marchantiophyta*) with species like *Riccia* species, *Marchantia* species, Hornworts (*Anthocerotophyta)* with species like *Phaeoceros laevis* and Mosses with species like *Polytrichum commune, splachnum* species, *Sphagnum species.* The checklist of Bryophytes identified in this region is given below.

I. <u>Liverworts</u>

1. *Marchantia linearis*
2. *Riccia billardieri*
3. *Riccia fluitans*
4. *Riccia gangetica*
5. *Porella acutifolia*
6. *Anthoceros bharadwajii*

II. <u>Mosses</u>

1. *Aerobryum speciosum*
2. *Entodontopsis nitens*

3. *Aerobryidium membranacea*
4. *Aerobryidium longissima*
5. *Stereophyllum acuminatum*
6. *Stereophyllum confusum*
7. *Cryptopapillaria fuscescens*
8. *Diaphanodon blandus*
9. *Ectropothecium buitenzorgii*
10. *Ectropothecium densum*
11. *Hypnum plumaeforme*
12. *Symphyodon pygmacus*
13. *Entodon prorepens*
14. *Isopterygium lignicola*
15. *Trichosteleum monostictum*
16. *Himantocladium strictum*
17. *Trichosteleum monostictum*
18. *Himantocladium strictum*

B. Pteridophytes:

Pteridophytes are counted here, mainly the ferns belonging to the families like Psilotaceae, Lycopodiaceae, Ophioglossaceae and Cyatheaceae. The checklist of the species recorded is given below.

1. *Adiantum hispidulam*
2. *Adiantum lunulatum.*
3. *Asplenium nidus*
4. *Asplenium lunulatum*
5. *Selaginella bryopteris*
6. *Selaginella barbata.*
7. *Selaginella plumose.*
8. *Cyrtomium falcatum*
9. *Blechnum orientale*
10. *Cyathea magnifolia*
11. *Cyathea glabra*

12. *Cyathea sinuata*
13. *Cyathea glabra*
14. *Cyathea spinulosa*
15. *Aneimia tomentosa*
16. *Nephrodium fragrans*
17. *Nephrolepis multiflora*
18. *Nephrolepis cordifolia*
19. *Cyrtomium caryotideum*
20. *Davallia bullata*
21. *Blechnum orientale*
22. *Cheilanthes farinosa*
23. *Cheilanthes argentea*
24. *Pellaea falcata*
25. *Pellaea rotundifolia*
26. *Pleopeltis macrocarpa*
27. *Pyrrosia mollis*
28. *Tectaria macrodonata*
29. *Ceratopteris thalictroides*
30. *Lycopodium cernum*
31. *Lycopodium clavatum*
32. *Lycopodium diaphanum*
33. *Osmunda regalis*
34. *Dryopteris sparsa*
35. *Dryopteris palmate*
36. *Phaneroplebia caryotidea*
37. *Polystichum aculeatum*
38. *Hemionitis arifolia*
39. *Polypodium vulgare*

40. *Polypodium phegopteris*
41. *Platycerium bifurcatum*
42. *Pisilotum comlanatum*
43. *Lepisorus nudus*
44. *Pteris cretica*
45. *Pteris vittata*
46. *Equsetum debile*
47. *Ophioglossum*
48. *Psilotum nudu*

2. Ecological functions:

Distinctively, riparian zones show many unique ecological characters. The floristic composition in the spray zone is found to be decisive in the functions like river bank stabilization and landscape stabilization of the adjacent regions. They also supply woody debris, organic matter, nutrients and also the shade to maintain the water temperature. Therefore, these dynamic interactions between forest and streams need to be further studied with special reference to the evergreen forests of *Western Ghats* region. Some of the important findings of this study are:

2.1 Stream width:

The width of riparian zone remains very less, that is about 3 to 6 Meters in the streams above 600 MSL altitudes. Whereas the II–order streams in the altitude range of 200 to 600 MSL show widening of river course, of about 6 to 10 Meters. The I-order streams flowing further down, that is below 200 MSL altitude show rapid widening. Both *Mundaje & Shishila* rivers, the major tributaries of *Netravati* River, have been more than 50 Meters wide in further course below 150 MSL altitudes.

2.2 Factors that influence the riparian zone:

It is observed that the reproductive biology of thee plant species in riparian zone is in some way linked to the dynamics of water in the stream and allied ecological parameters like the average soil moisture in the riverbed and the bank, shade pattern, the seasonal variation in soil moisture, soil temperature, the slope gradient deciding the run off water speed, water temperature etc. That means, all these factors together contribute to create such niche habitat, which would ensure the continuation of lifecycle of these plant species. Therefore, they are not found beyond riparian zones. The images of these representative landscapes across the study region in at different altitude ranges are given in the **Plate** section.

2.3. Physico-chemical properties of stream water:

The stream water qualities in terms of basic physico-chemical properties are studied by taking periodic samplings in designated collection pots. They are analyzed by standard methods. The water seems to be free from any pollution load, except the traces of excess organic matter nearby the human settlements, in the downstream ranges of these rivers. The overall characters of the water quality in 10 major streams studied in *Mundaje* & *Shishila* rivers are summarized below.

Hydrological Physico-chemical properties of streams of *Mundaje & Shishila* rivers.

Season	**pH**	**Average Temperature**	**Turbidity**	**Color**	**Organic matter Load**	**Total Salts**
Summer (Sampling in April-May)	6.2	21^0 C	Transparent	Colour Less	14.8%	6.5mg/l
Monsoon (Sampling in July-August)	5.2	18^0 C	Turbid	Muddy	30%	18.0mg/l
Winter (Sampling in December-January)	6.6	15^0 C	Crystal Clear	Colour Less	11%	4.4mg/l

2.4 . Key factors that that governs water flow in steams:

Detailed studies are made on the potential factors, which may influence the pattern & volume of water flow in these perennial streams. The key factors governing the average water volume in these streams of *Netravati* River systems are aspects like rainfall in the catchments area, terrain patterns of the catchments, vegetation type on the catchments, vegetation type on the river bank and the edaphic characters of the river bank & river bed. It has been clearly observed that, it is the plant diversity and plant density of the vegetation cover in the immediate bank and the adjacent catchments, which is primarily responsible for deciding quantity and quality of water flow in the streams and maintenance of flow in a given precipitation condition. Their overall effectiveness are depicted in **Graph-I.**

2.5 Water discharge pattern:

What factors determine the water discharge rate from the adjoining catchments area to the stream course? It was one of the key questions assessed in this study. The correlation between the water discharge pattern and rive bank quality are recorded for different streams. It showed that the water flow pattern in terms of volume of water discharged per unit area, is higher in the river bank regions, which are relatively more de-forested and degraded. This indicates that the quality green cover and effective soil management practices in the catchments areas prevent the soil erosion and reduces the run off water speed. This is shown as a Hydrograph in the **Graph-II.**

2.6 Average monthly flow:

The average monthly water flow is studied for all the streams studied in the *Netravti* River system. The average flow rate indicates that flow volume and runoff speed

would be at the peak during July – August period and low at March –April period. This has been indicated in the **Graph-III**.

2.7 The Physico-chemical properties of the soil in riparian zone:

The river bank soil, which forms the representative habitat of riparian flora, apart from the river herbs and shrubs, is studied by standard sampling and laboratory investigation techniques. The details are summarized in the table given below. The characteristic features of this soil are: high relative humidity, relatively low pH, loamy soil with high sticky nature.

Physico-chemical properties of the soil
(In the banks of streams of *Mundaje* & *Shishila* Rivers)

Season	**pH**	**Average Temperature**	**Moisture Content**	**Color**	**Organic matter Load**	**Sticky Nature***
Summer (Sampling in April-May)						
River Bed Soil	5.1	20^0C	90%	Brown Sandy	10.5 %	2
River Bank Soil	6.3	28^0C	5%	Black Loamy	45.0 %	4
Monsoon (Sampling in July- August)						
River Bed Soil	4.2	18^0C	90%	Brown Sandy	17.5 %	1
River Bank Soil	5.9	20^0C	85%	Red Loamy	78.0 %	8
Winter (Sampling in December-January)						
River Bed Soil	5.0	15^0C	90%	Brown Sandy	13.5 %	2
River Bank Soil	6.5	18^0C	73%	Red Loamy	71.0 %	5

*** In the scale of 1 to 10.**

3. Land use pattern:

The core riparian zone actually extends from the mid course of the river to about 50 Meters. However, the buffer zone of about 30 to 50 Meters beyond this high tide line has several riparian features. However, both this core zone and buffer zone are very much influenced by different land use / management regimes and practices. They are all summarized below. The overall scenario is that intensive land use by multiple stakeholders is inversely proportional to the riparian floral diversity.

Land use pattern

Region	Regime	Management Practices
I- Order Streams		
Core Riparian Zone (Below high Tide Line)	KFD	Impact by occasional visits by hunters & NTFP collectors
Buffer Zone (Beyond High Tide Line)	KFD	Impact by occasional visits by hunters & NTFP collectors
II- Order Streams		
Core Riparian Zone (Below High Tide Line)	KFD.	Impact by occasional visits by fishing people, hunters & NTFP collectors.
Buffer Zone (Beyond High Tide Line)	• KFD. • Revenue Farmland • Encroachments	• Impact by occasional visits by hunters & NTFP collectors. • Cutting of trees
III- Order Streams		
Core Riparian Zone (Below High Tide Line)	KFD	• Impact by occasional visits by hunters & NTFP collectors • Regular fishing • Sand mining & Boulders collection • Collection of riverbed trees & shrubs
Buffer Zone (Beyond High Tide Line)	• KFD • Common Land • Revenue Farmland • Encroachments	• Farming, Grazing • Firewood & timber collection • NTFP & Leaf-litter collection • Soil excavation

4. The threat status:

The threat assessment in these ecosystems is done by documenting the anthropogenic pressures. Initial field visits indicate that several factors like encroachment, unsustainable harvest of Non-Timber Forest Products (NTFP) like *Cinnammomum*, timber logging, extended cultivation, poor river bank management etc. are found to be the major causes for the degradation of many spots in these zones. Apart from the biodiversity and ecological value, the conservation of these habitats is very much directly linked to the livelihood security of the people too. Studies elsewhere have shown that the destructions in the upper reaches of any river valley regions in *Western Ghats* could lead to severe water scarcity in the down stream. As the entire *Dakshina Kannada* population depends upon *Netravati* River for its water security, the conservation of the riparian zone in upper reaches is of immediate concern.

A few public consultation meetings were organized as part of this action research exercise to asses the opinion of local people. Their experience and opinions are also taken into consideration, while short listing the following threats. They are in the descending order of their severity.

1. Sand mining in the riverbed.
2. Encroachment in the buffer zone and the catchments.
3. Collection of boulders and removal of river bed flora for the purpose of firewood.
4. Unscientific and illegal construction of houses.
5. Extended farming till the river bank edges.
6. Unscientific soil excavation in the buffer zones.
7. Illegal fishing, hunting.
8. Overuse/diversion of river water in winter & summer for the commercial purpose.
9. Unsustainable harvest of Non-Timber Forest Produce (NTFP).

10. Excess collection of leaf, litter, firewood, green leaves etc. by the nearby farmers & forest dwellers.

5. Conservation strategies:

Riparian ecosystems form very unique ecosystems in the evergreen forest region of perennial rivers of *Western Ghats.* There is need of carrying out further wider studies and designing conservation strategies. Keeping the increasing water scarcity in the coastal and central *Deccan Pleatue* in peninsular India, the conservation of riparian zones assumes high significance. The educational institutions could play a major role in the conservation process of these unique wetland regions by giving regular feedback to the local offices of government departments for ensuring effective management practices. Thus, these fragile ecosystems need further attention, especially in these *Western Ghats* region, for ensuring conservation efforts.

Based on the outcome of this study, the following remedies are suggested keeping their long term sustainable management in view.

a) The forest department can come up with micro planning for all these habitats in association with civil society organizations and also the Biodiversity Committees of *Grama Panchayats*. The Village Forest Committees (VFC) can also join for this purpose. The local academic institutions like schools and colleges can constantly monitor the status of the ecosystems by gathering data and regularly upgrading it.

b) Enforcing *in-situ* conservation principle by enforcing stringent forest protection rules in order to prevent encroachments, smuggling, illegal sand mining, unscientific harvest of NTFP & firewood etc.

c) Bringing in new *in-situ* conservation modes like that of declaring those pristine pockets as 'Conservation Reserve' (under Wildlife Protection Act) or 'Heritage Sites' (Under Biodiversity Conservation Act).

d) Adopting *ex-situ* conservation models for the riparian plant species with special focus on IUCN Red listed & endemic plants, by giving all support to the local sapling raising nurseries maintained by dept. of forest. That means the Dept. of Forest needs to explore the opportunities for developing proposals to consider them as candidates for providing these legal tags.

e) The mapping should be done for these ecologically unique habitats like *Myristica* swamps, reeds habitats, spray zone systems, fresh water pools in river systems, tall & big girth riparian trees, regions of IUCN Red listed & endemic plant species etc. all along these perennial streams in the upper catchments areas of *Netravti* River and incorporating provisions in the working plan of KFD for their regular protection.

f) Raising and re-introducing the major riparian woody flora, with special focus on Rare, Endemic, Endangered, Threatened & Endemic species, in their original riparian habitats with the participation of local communities.

g) Promoting and empowering Village Forest Committees (VFC) in these regions in order to ensure further participation of people in the conservation activities and programmes.

6. Inputs for developing policy / governance:

The overall ecological status like the river flow, the bank cover, human impact etc. were observed and the reasons are inferred. The ecosystems are relatively healthy in first and second order streams, beyond the high tide mark. However, the anthropogenic pressures like encroachment, sand mining by local construction business, unsustainable harvest of Non- Timber Forest Produce (NTFP), extended cultivation etc. are widely seen

and increasing day by day. All these factors may lead to the loss of this pristine ecosystem. These are seen in high intensity in down steams, especially in the steams of third order. Such a trajectory would lead to the loss of ecologically significant riparian flora and fauna. That may also lead to the river bank erosion, loss of top soil in adjacent forest etc, which in turn would certainly lead to rapid depletion of water resource in the river system. Therefore, three is a need of taking some concrete steps in order to protect this ecosystem.

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Chapter 7.

Conclusions.

Based on the field studies and the data analysis works done as part of this research project, the following conclusions are drawn.

1. Ecosystem Services:

The riparian areas are the regions where land interfaces with rivers or streams. Even the term 'Riparian' is reflected in the nomenclature of biomes of the earth, being one of the fifteen terrestrial biomes. Plant habitats and communities along the river edges and banks are therefore called riparian vegetation, characterized by hydrophilic plants. Riparian zones are significant in ecology and environmental management, because of their role in soil conservation and influencing the unique nature of this habitat. The riparian woodland, riparian forest, riparian buffer zone and riparian strips are conserved all over the world because of their unique structure and vital functions.

Many 'Ecosystem Services' are enumerated in the context of riparian ecosystems. The important among the mare:

a) **Habitat of biodiversity:** The riparian zones of are the habitats of diverse forms of life, both plants and animals. This study is done only on the woody flora. There is much biodiversity beyond this study like lower groups of plants and aquatic animals. Therefore, riparian zones certainly represent a niche habitat, with rich biodiversity of central *Western Ghats* with many possible Rare, Endangered, Threatened and Endemic species.
b) **Water Quality:** Riparian forest buffers help maintain water quality. They reduce the amount of pollutants in runoff — such as sediments, nutrients, pesticides, and fecal *Coliform* bacteria — from entering streams. Riparian forest buffers shade

streams, maintaining cooler water temperatures and healthy levels of dissolved oxygen, which is important for aquatic habitat. They attenuate nitrate or cause the de-nitrification of the nitrates brought from surface runoff. It takes place in these buffer zones. Riparian zones can thus play a significant role in lowering nitrate contamination in surface runoff from agricultural fields, which would otherwise damage ecosystems and human health.

c) **Watershed Development value:** The riparian buffer acts as cushion for absorbing rain water and run off water and enriches the ground water. It is this ground water stock which feeds the rivers, rivulets and wells etc. in the downstream region, which make them perennial. Therefore, the watershed development functions of these riparian zones are vital inters of ground water recharging and water security in the command area.

d) **Regulating water quality:** Riparian forest buffers also help regulate water quantity. During a flood, trees reduce the velocity of the water, allowing more water to infiltrate into the ground and recharge groundwater supplies. This enables water to be released more slowly and over longer periods of time. The reduced velocity of water and increased infiltration also helps minimize the magnitude of downstream flooding.

e) **Wildlife Habitat:** Riparian forest buffers are critical for the survival of many wildlife species. They serve as safe travel corridors between land and water, provide a reliable food source, and serve as areas of cover. Many fish and bird species depend on the insects that live in forested riparian areas for food. Many threatened and endangered species require the presence of forested areas along streams to survive. Trees also act as a source of nutrients and woody debris that are important as a source of food and shelter for aquatic invertebrates, fish, reptiles, and amphibians. Stream bank Stabilization

f) **Stability of stream banks:** Riparian forest buffers are important for the stability of stream banks. In addition to smaller roots found mainly in the upper 8 inches of the soil, trees send larger roots into the ground vertically and laterally and use those roots as anchors to hold them in place. These larger roots help hold the soil and reduce the amount of erosion. After a flood, non-forested stream banks have been found to have significantly more erosion than forested banks. Forested stream banks have even shown overall deposition of sediment. With high water flows, as the trees slow the velocity of the water, sediment has more time to settle out, allowing soil to accumulate in the forested areas. Trees also stop large debris carried by the floodwaters from entering fields and other land.

g) **Source of income:** Maintenance of the riparian forest buffers is necessary to ensure that the trees remain healthy and the buffers continue to function effectively. Timber stand improvement helps to foster the vegetation that will most effectively remove pollutants from runoff and subsurface flow before it reaches the water. Maintaining riparian forest buffers for desirable species may provide a profit when trees become mature and ready for harvest. This will not only be a financial gain, but will also ensure the future effectiveness of the riparian forest buffer.

h) **Source of livelihood:** Riparian zones with their diverse natural resources like plants, animals and minerals act as the crucial livelihood source for the local communities and sustainable income for the regulator agencies. Fishing, NTFP, minor minerals timber, firewood, green manure etc. can be named here. No study is done so far for quantifying their economic worth in terms of Environmental Economics. Therefore, there is a need of taking such further study for these very rich ecosystem, But, this primary investigation certainly tells that they play major role in sustaining the livelihood security of the local people.

i) Other ecosystem services:

- Riparian zones may be natural or engineered for soil stabilization or restoration.
- These zones act as important natural bio-filters, protecting aquatic environments from excessive sedimentation, polluted surface runoff and erosion.
- They supply shelter and food for many aquatic animals and shade that is an important part of stream temperature regulation.
- If the area adjacent to a watercourse has standing water or saturated soil for a long season, it is normally termed a wetland. Because they start showing wet soil characteristics.
- Riparian zones dissipate stream energy. The meandering curves of a river, combined with vegetation and root systems, dissipate stream energy, which results in less soil erosion and a reduction in flood damage.
- Sediments are trapped by riparian vegetation and that would help in reducing suspended solids to create less turbid water, replenish soils and build stream banks.
- Pollutants are filtered from surface runoff, which enhances water quality via bio-filtration.
- The riparian zones also provide wildlife habitat, increase biodiversity, and provide wildlife corridors, enabling aquatic and riparian organisms to move along river systems avoiding isolated communities. They can provide forage for wildlife and livestock.
- They provide native landscape irrigation by extending seasonal or perennial flows of water.
- Nutrients from terrestrial vegetation (e.g. plant litter and insect drop) are transferred to aquatic food webs.

- The vegetation surrounding the stream helps to shade the water, mitigating water temperature changes.
- The vegetation also contributes wood debris to streams which is important to maintaining geomorphology.

However, as population and farming practices are being expanded, forests throughout *Dakshina Kannada* district, including those in riparian areas, have been converted for agricultural and other commercial purposes. This is considerably reducing forestland here. The re-establishment and management of riparian forests is important for restoring and maintaining the water quality in entire *Netravati* River command area in *Dakshina Kannada* district. Riparian forests can improve and maintain water quality, regulate water quantity, stabilize stream banks, provide wildlife habitat and recreational activities. Whenever and wherever the riparian zones are damaged by factors like resource exploitation, construction, agriculture activities etc., biological restoration process needs to be directed by bringing in positive interventions like erosion control and re-vegetation

2. Relevance and implications of the outcome of this research project:

2.1 Ecological significance*:*

Riparian zones of evergreen forest are one such important ecosystem. Riparian vegetation is nothing but an eco-tone, interacted by forest & rivers. It can also be called the transitional belt between water and the land along the river. Riparian vegetation generally shows three distinct zones: Stream bank flora, river course flora & aquatic flora. While the first one is dominated by trees, climbers and shrubs, the later two are occupied by shrubs, herbs and sometime the saplings of trees. They are considered to be performing many vital functions like regulation of water temperature by providing shade, causing the sediment settling, reducing the rate of flow of water in streams, providing regular nutrient load, stabilizing the stream bank, reducing the erosion, nourishing the riparian habitat,

maintenance of fish habitats, offering a green belt along he bank and so on. Thus, their role in regulating water cycle of the forest floor, nutrient cycles of the lower command area, creation of breeding sites for many sensitive organisms etc. are found to be very crucial. These ecosystems are now being widely studied across the tropical region due to this increasingly evident significance.

2.2 Riparian flora: **The taxonomic significance**

Riparian zones are seen abundantly in the *Western Ghats* as many perennial rivers take births in the evergreen forest of the region. They are contributing much to the biodiversity in the *Western Ghats*, especially the floristic diversity. The taxonomical investigations in *Western Ghats* region have shown that there are many plants, which are distributed only in the riparian zone. Some of the important species are: *Madhuca nerifoila* H.J.Lam., *Syzygium heyneanum* Duthhic., *Holigarna arnotiana* Hook., *Ochreinauclea missionis* Ried., *Ochlandra scriptoria* Fischer., *Neolamarkia cadamba* Roxb., *Callophyllum apetalum* Wild., *Cinnammomum riparium* Nees., shrubs like *Homonoia riparia* Lour., *Polygonum glabrum* Willd. and herbs like *Rotula aquatica* Lour.

2.3 Structural & functional uniqueness of riparian vegetation:

These riparian zones also show some unique ecological characters. The floristic composition in the buffer zone is found to be decisive in the functions like river bank stabilization and landscape stabilization of the adjacent regions. They also supply woody debris, organic matter, nutrients and also the shade to maintain the water temperature. Riparian vegetations have often sustained tremendous interference from human activity from time immemorial as they sustain the human population too, but relatively less in the hilly terrain of the *Western Ghats*. A periodic variation in the watershed hydrology produces frequent floods and they impact the water supply, sediment balance and

morphological changes in the flood plain. They affect the structure & composition of the riparian vegetation too. In other words, the riparian vegetation is influenced by variations in the catchments hydrological characters. Elaborated studies are being done world over on all these major aspects like taxonomic and ecological uniqueness studies, its dynamics over a period of time as an ecosystem and the present challenges in their conservation. Considerable research efforts have been also gone into the all potential modes of conservation of these ecotone areas too. As in the case of *Western Ghats* of peninsular India, for instance, most of the rivers take birth in the this hilly terrain region having huge command area, their ecological studies have relevance with the socio-economic life of the down stream too. Therefore, these dynamics of forest and stream interactions need to be further studied with special reference to the riparian zones of evergreen forests in *Western Ghats* region.

2.4 The propagation methods of a few major riparian Angiosperm species which are threatened & endemic.

Many riparian Angiosperm species found in the upper *Netravati* streams belong to ecologically significant groups like that of IUCN Red List and endemic categories. Therefore, the conservation of the habitat is crucial for the survival and progression of these plant species as well. However, along with the *in-situ* conservation efforts, there is very much need to taking their ex-situ conservation also. The nurseries of the forest department and other similar enterprise need to incorporate them in their regular raising and distribution programs. Keeping this objective in mind, the phenology of some key riparian species is studied and the summary is given below. A ready thumb rule is also developed, which can help the people who are directly involved in the raising such species in the filed.

1. Ochreinauclea missions Ried.

Flowers crowded in globose, usually solitary, terminal heads, yellowish-white, fragrant. Calyx tube turbinate, tomentose, lobes 5. Corolla tube, funnel-shaped, tomentose, lobes 5. Stamens 5, on the throat of the corolla. Ovary 2-locular; style filiform; stigma capitate. Fruit a fleshy globose, mass of 2-celled pyrenes, yellow when ripe. Seeds are many, ovoid. Flowering season is in April to August and fruiting is in October to December.

2. Neolamarkia cadamba Roxb.

Flowering season: starts in April–August, sometimes March–November, and the fruits mature in June–August. Special techniques are required to extract the minute seeds from the fleshy multiple fruits.

Successful extraction of seeds from ripe fruits involves air drying, crushing and sieving. The fruits are soaked in an open area until rotten, ground by hand into a thick slurry, air-dried and passed through a series of sieves. This procedure improves the germination rate up to 98%. (According to *Soerianegara* and *Lemmens* (1993), the weight of 1 million air-dried seeds is about 38–56 g.). Seeds should be stored in dry, airtight containers. Properly stored seeds can remain viable for up to 2 years, and up to 6 months at an ambient temperature (*Jøker* 2000). According to *Martawijaya et al.* (1989), dried seeds stored in airtight containers in a moist room will retain viability for about 1 year. The germination rate of fresh seeds is variable, but generally low at about 25%. When seeds are stored in cool, airtight boxes for about 2.5 months, a much higher germination rate (up to 95%) can be obtained.

3. Homonia riparia

Fruit an ovoid to slightly coccoid rhegma, outside sericeous, inside glabrous, dehiscing loculicidally and later also partly septicidally into 3 bivalved segments; wall thin, woody; septa with a basal vein and a vein halfway (at apex of column); column after dehiscence with a narrow straight septum margin, apically tapering, not

broadened. *Seeds* usually 3 per fruit, ovoid, but keeled at one side, somewhat flattened; arillode sarcotesta-like, covering seed completely, red. *Embryo* flat, without endosperm. It is a 'Rheophyte', having mostly found in and along rivers at low altitudes.

H. riparia most specimens only show staminate or pistillate flowers, which probably indicates dioecy. Several specimens contain separate branches (perhaps from different plants), each with flowers of one sex, but with both sexes present. A handful of specimens show flowers with mixed inflorescences on the same branch, some with staminate flowers, and others with pistillate flowers, and several with staminate flowers basally and pistillate flowers apically. These plants are of course monoecious. Perhaps the species is monoecious and the different sexes appear on the same plant, but separated in time and on different inflorescences. Flowers are presumably wind pollinated. They are small and easily carried away but he water current. Flowering and fruiting can be seen throughout the year.

4. Actinodaphne bourdillonii Gamble.

Flowers unisexual, dioecious, in umbels on short peduncle. Fruit is a berry and black when ripe. Seated on cup shaped fruiting perianth having only one seed. Flowering season is February to May and fruit ripening period is May to August.

5. Ochlandra scriptoria Fischer.

Although flowering is reported to be annual, it is not very frequent. The length of the fruit vary from 2.8 to 3.9 cm with a beak of 2.7 to 3.4 cm. Fresh weight is 1.56 to 1.6 gm/fruit. One kilogram contains about 625 to 640 fruits. The moisture content varies from 65 to 70 per cent (*Seethalakshmi,* 1993).

6. Rotula aquatica

Seeds are sown after collection in nursery beds filled with sand and soil mixture, partial shade is necessary for initial two months. Initial germination is about 70 per cent.

Seeds are viable only for a period of two months (*Seethalakshmi,* 1993). Seedlings can be transplanted after a period of one year. Rhizomes can be separated from the culms during the onset of monsoon and can be used for field planting. Two-noded culm cuttings treated with IBA 100 ppm give the highest percentage of rooting in culm cuttings (50%). The rooting and shooting responses can be significantly enhanced by the application of suitable growth regulating substances. The cuttings can be planted horizontally in nursery beds.

7. Calophyllum inophyllum

Natural regeneration usually occurs near the mother tree. Seedlings grown in nurseries require shade. Removal of the endocarp significantly reduces the germination period to about 22 days, increases the germination rate and improves seedling growth and development. Initial growth is slow and repeated weeding is necessary. There are up to 200 seeds/kg. Seed storage behavior is recalcitrant**.** Flowering season is December to February and fruit ripening period is April to June. The seeds can be thus collected in June, which gives 170 to 200 seeds per kg. The seeds show only 25 to 40% germination rate and remain viable only for 3 to 4 months. The seeds would take a month to germinate and they can be transplanted thereafter to nursery bed. The 5 to 6 months old saplings can be transferred to filed.

8. Callophyllum apetalum L.

Flowers are white and found in axillary panicle. Flowers are seen in clusters of 4–15 fragrant white flowers about 2.5 cm (1 in) across and 8–14 mm (0.3–0.6 in) long on long, sturdy stalks in leaf axils. There are 4–8 oblong petals. Flowering is heaviest in late spring/early summer and fruit ripening period is May to August.

Fruit is a yellowish drupe and brown, ovoid to ellipsoid, to about 1.5 cm long with only one seed. The ball-shaped, light green fruits grow in clusters. The skin, which turns yellow and then brown and wrinkled when the fruit is ripe, covers the thin pulp, the shell, a corky inner layer, and a single seed kernel. Fruits are usually borne twice a year.

Seeds are large brown and of about seed 2–4 cm in diameter. Seeds are prepared by cleaning off the skin and husk from the shell of the seed; there are 100–200 seeds/kg (45–90 seeds/lb), with shells intact but husks removed.

9. Vitex leucoxylon L**.**

The flowers are seen in corymbose cyme inflorescence. Usually they are axillary, minutely pubescent; zygomorphic, sessile; corolla white with purple anther lobes. Fruits are drupe smooth, obovoid and purplish black, usually with 4 seeds. Flowering season is February to May and fruit ripening period is May to August.

10. ***Madhuca neriifoila*** H.J.Lam

Flowers are yellowish-white, in axillary fascicles; pedicels ca. 0.8 cm long. Fruits are berry, fleshy, ellipsoid, beaked having one brown seed. Flowering season is February to May and fruit ripening period is May to August.

Thumb rule for propagation of major riparian species

No	Name	Propagation Material	Seed collection & treatment	Nursery Bed Technique
1	*Ochreinauclea missions*	Seed	October/ November	Shade Dry before sowing. Transplant after 5 months to the field.
2	*Neolamarkia cadamba*	Seeds	July / August	Cold treatment before sowing Transplant after 15 months to the field.
3	*Rotula aquatica*	Rhizome	Early Monsoon	Treat with NAA dilutions. Two-noded culm cuttings can be horizontally buried in the nursery bed. After 4 months transplantation can be done
4	*Homonia riparia*	Root / Stem Cuttings	Soon after winter	Cuttings can be vertically planted in sand rich nursery bed. After 4-5 months transplantation can be done
5	*Actinodaphne bourdillonii*.	Seeds	July / September	Air dry and roll in ash before sowing. Transplant from nursery bed after 10 t o12 months.
6	*Ochlandra scriptoria* .	Stem cuttings / Rhizomes	January	Cuttings are deeply laid in the sand rich n raised nursery bed and soil is pressed above to make the bed compact. The sprouted cuttings (from the nodes) can be transplanted after 4 to 5 months.
7	*Callophyllum inophullum*	Seeds	May / August	Dip the seeds in hot water once and soak in cold water for over week before sowing. Transplant after10 to 12 months from the nursery bed.
8	*Callophyllum apetalum*	Seed	June / September	Dip the seeds in hot water once and soak in cold water for over week before sowing. Transplant after10 to 12 months from the nursery bed.
9	*Vitex leucoxylon*	Seeds / Stem Cuttings	May/ June	Seed or Stem cuttings can be laid in the sand and humus rich nursery beds under shade Transplantation can be done after 6 moths
10	*Madhuca neriifoila*	Seeds	June / September	Mature seeds should be collected from the trees, which are started germinating and transferred to sunken nursery bed. Transplant after10 to 12 months from the nursery bed.

3. Achievements of the project:

1. The riparian zones of the study area are identified, demarcated and thereat perceptions are assessed.
2. The exclusive riparian Angiosperm flora is documented.
3. The soil and water properties of the riparian zones are assessed and defined.
4. The possible reasons for the high watershed properties of the some streams assed.
5. The riparian zone restoration practices are standardized and suggested as remedial package.
6. Local people and community based organizations were involved in the filed sampling procedure so as to keep them informed as well as make them apprised of the significance of the riparian flora. More than 50 people got such first hand interaction during the last one year study works.

4. Contributions to the society:

- Ecologically sensitive river valley regions in the central *Western Ghats* region are identified for this major perennial river system.
- The unique riparian Angiosperm flora is documented including IUCN Red List categories, Endemic & medicinally important species.
- The role of riparian flora in enhancing the watershed value of the river is established and thereby their importance in ensuring livelihood security of the people in the downstream area.
- The riparian zone restoration methods are short listed and given as package of practice.

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Chapter 8.

Recommended conservation strategies

The *Netravati* River Riparian Ecosystem zone in the upper reaches of *Netravati* River system in the Belthangady taluk comprises the foothills of *Western Ghats.* The principle perennial streams like *Mundaje*, *Neriya* & *Shishila* rivers are studied during this project work. Some of these stretches can be considered for declaring them as 'Biodiversity Heritage Site' (under the provisions Biodiversity Conservation Act), after further consultation with local communities.

1. Riparian ecosystem can be further restored and conserved with the active participation of local communities, especially the farmers having land holdings adjacent to the river systems all along, through the intuitional mechanisms like Village Forest Committees. (VFCs).

2. Further ecosystem enrichment can be done by planting riparian species *like Aanthocephalus cadamaba, Ochreinuclea missionis,* wild Mango (Pickle varieties), Bamboo, *Panadanaus species, Ochlandra species, Pongamia pinnata* , *Callophyllum apetalum* etc.

3. The Mundaje river belt is relatively degraded and therefore that region needs to be further enriched by planting sacred riparian species like *Saraca asoca, Syzygium travancorica , Madhuca neerifolia etc.*

4. The Biodiversity Management Committees (BMC) should be formed in all the *Grama Panchyats* in the *Netravati* River catchment area and they should be

empowered to take the stock of the situation in terms of riparian zone protection. This needs to be done on priority in *Mundaje, Chramady & Arasinamakki Grama Panchaayata* area.

5. The sand mining, rock excavation activities, fishing by using dynamites, river bank encroachment etc. are observed in many places, nearby to village clusters. They need to be controlled through institutional mechanisms like Village Forest Committees (VFC) & Biodiversity Management Committees of *Grama Panchayat.*

6. A special nature trail can be laid with educative measures like labeling of unique riparian plants of this region along the river bank, near the *Mundaje* Irrigation Bridge. A mud pathway up to river floor can be laid and well depicted display board can be erected at the entrance of such trials.
7. These ecosystems are now being widely studied across the tropical forest ecosystems because of their huge biodiversity potential & vital ecosystem services. Therefore, further studies can be done for assessing the flora, fauna, ecosystem functions, threat assessment, hydrological potential etc.

8. Many big trees of *Calophyllum apetalum, Anthocephalous cadamba, Ochreinauclea missions,* giant woody climber Entada *pusaetha* etc are seen abundantly here. They need to be protected through mechanisms like declaring them as heritage trees.

9. This is one of the pristine zone having riparian species like *Ochreinauclea missions, Anthocephalus cadamba, Syzygium zeylanica, Calophyllum apetalum, Pongamia pinnata* etc. The Forest Department can use these mother trees for collecting

propagation materials for raising saplings in nurseries and other *ex-situ* conservation programs.

10. The nurseries of *Dakshina Kannada* district, especially the ones in the *Belthangady* and *Puttur* Forest Ranges, should be encouraged & supported to take up the regular nursery activities, giving emphasis on these riparian plant species.

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Annexures

Annexure-I

Table-1.

Checklist of Angiosperm plant species recorded in Riparian Zones of *Netravati River system* in Belthangadi taluk of *Dakshina Kananda*

I.

No.	Species	Local Name	Family
1.	***Adina cordifolia,*** Hook	Hedde	Rubiaceae
2.	***Albizia chinensis*** (L.)Benth	Baage	Mimosaceae
3.	***Albizia procera*** (L.)Benth	Bili Baage	Mimosaceae
4.	***Alstonia scholaris*** (L.) R.Br.	Maddale	Apocynaceae
5.	***Aporusa lindleyana*** (Wight.)Baillon	Salle	Euphorbiaceae
6.	***Asparagus racemosus*** Willd.	Shatavari	Liliaceae
7.	***Bambusa aurundinacea*** (Retz.) Roxb.	Bidiru	Poaceae
8.	***Bridelia retusa*** (L.)	Bisle hannu	Euphorbiaceae
9.	***Buchanania lanzan*** Sprengel.	Nurukalu	Anacardiaceae
10.	***Caesalpinia mimusoides*** (L.) Roxb.	Kenjige	Caesalpiniaceae
11.	***Calycopteris floribunda*** Lam.	Kumbasalu	Combretaceae
12.	***Careya arborea*** Roxb.	Kavalu	Lecythidaceae
13.	***Carissa congesta*** Wight.	Kavali	Apocynaceae
14.	***Caryota urens*** L**.**	Baine	Arecaceae (Palmae)
15.	***Cassia fistula*** L.	Kakke	Caesalpiniaceae
16.	***Celtis timorensis*** Span.	Hetari	Ulmaceae
17.	***Chassalia curviflora*** (Wallich.)	Garuda pathala	Rubiaceae
18.	***Catunaregam spinosa*** Thunb.	Kaadu Kare	Rubiaceae
19.	***Cissus javanica*** Blume.	Hacchambarive Balli	Vitaceae
20.	***Clerodendrum inerme*** L**.**	Bili Taggi Gida	Verbenaceae
21.	***Clerodendrum viscosum*** Vent.	Taggi Gida	Verbenaceae
22.			

23.	***Crotalaria juncea*** L.	Giji-giji Gida	Leguminiosae
24.	***Dalbergia latifolia*** Roxb.	Beete	Leguminiosae
25.	***Dillenia pentagyna*** Roxb	Kanagilu	Dilleniaceae
26.	***Dioscorea bulbifera*** L.	Kadu genasu gadde	Dioscoreaceae
27.	***Diospyros assimilis*** Bedd.	Kariara	Ebenaceae
28.	***Diospyros buxiufolia*** White.	Sannele karimara	Ebenaceae
29.	***Diospyros montana*** Roxb.	Balgane	Ebenaceae
30.	***Embelia tsjeriam-cottam*** (Roem.)	Vidanaga	Myrsinaceae
31.	***Entada scandens*** (L.) Benth.	Ganape balli	Mimosaceae
32.	***Ficus asperrima*** Roxb.	Garagatti	Moraceae
33.	***Ficus racemosa*** Willd.	Atti	Moraceae
34.	***Ficus religiosa*** L.	Ashwatha	Moraceae
35.	***Gardenia gummifera*** L.F. (Baill)	Bikke	Rubiaceae
36.	***Grewia microcos*** L.	Chirkalu	Malvaceae
37.	***Grewia tilaefolia*** Vent.	Dadasalu	Malvaceae
38.	***Gymnema sylvestris*** Retz.	Madhunashini	Asclepiadaceae
39.	***Heliotropium indicum*** L.	Bhurundi	Boraginaceae
40.	***Hemidesmus indicus*** L.R.(Br.)	Halu Balli	Asclepiadaceae
41.	***Hibiscus furcatus*** Wal.	Kaadu bende	Malvaceae
42.	***Hydnocarpus pentandra*** (Buch.-Ham)	Surante	Flacourtiaceae
43.	***Ixora brachiata*** L.	Bili Hole Dasavala	Rubiaceae
44.	***Ixora coccinea*** L.	Kepmpu Hole Dasavala	Rubiaceae
45.	***Jasminum malabaricum*** Wight.	Kadu mallige	Oleaceae
46.	***Lagerstroemia lanceolata*** Wight & Arn.	Nandi	Lythraceae
47.	***Leucas aspera L.***	Tumbe	Lamiaceae
48.	***Lophopetalum wightianum*** Arn.	Banate	Celstraceae
49.	***Macaranga peltata*** L.	Chandakalu	Euphorbiaceae
50.		Kunkumad Mara	Euphorbiaceae

	Mallotus philippensis Lam.		
51.	***Mangifera indica*** L.	Midi mavu	Anacardiaceae
52.	***Mealstoma malabathricum*** L.	Nekkare	Melastomaceae
53.	***Mimosa pudica*** L.	Nachike Gida	Mimosaceae
54.	***Mitragyna parviflora*** Roxb.	Etagalu	Rubiaceae
55.	***Mucuna monosperma*** Wight.	Nasugunni	Leguminosae
56.	***Murraya paniculata*** L**.**	Kadu bevu	Rutaceae
57.	***Mussaenda frondosa*** L**.**	Bellotte soppu	Rubiaceae
58.	***Ochlandra rheedii*** Gamble.	Vote gala	Poaceae
59.	***Olea dioica*** Roxb.	Akkerkalu	Oleaceae
60.	***Pandanus canaranus*** Warb.	Mundige	Pandanaceae
61.	***Paramigyna monophylla*** Merr.	Kaadu kanchi	Rubiaceae
62.	***Passiflora foetida*** L**.**	Gante huvu	Passifloraceae
63.	***Piper hookeri*** Miq.	Kaadu menasu	Piperaceae
64.	***Pongamia pinnata*** L.	Hinge	Leguminosae
65.	***Persea macrantha*** Nees.	Gulmav/ Kurma	Lauraceae
66.	***Rauvolfia serpentine*** L**.**	Sarphagandha	Apocynaceae
67.	***Ricinus communis*** L.	Oudala	Euphorbiaceae
68.	***Santalum album*** L**.**	Shreegandha	Santalaceae
69.	***Smilax zeylanica*** L.	Hegganne Balli	Smilaceae
70.	***Solanum torvum*** Sw.	Kadu badane	Solanaceae
71.	***Stereospermum personatum*** Hassk.	Pathale	Bignoniaceae
72.	***Strychnos nux-vomica*** L**.**	Kasarka	Loganiaceae
73.	***Syzygium caryophyllatum*** L**.**	Sanna Nerla	Myrtaceae
74.	***Syzygium cumini*** L**.**	Nerale	Myrtaceae
75.	***Tabernaemontana heyneana*** Wallich**.**	Kodsa	Apocynaceae
76.	***Terminalia bellirica*** Roxb.	Taari mara	Combretaceae

77.	***Terminalia paniculata*** Roth.	Honagalu	Combretaceae
78.	***Terminalia tomentosa*** Roxb.	Kari matti	Combretaceae
79.	***Trema orientalis*** (L.) Blume	Kirihaale	Urticaceae
80.	***Vitex altissima*** L.	Baranige	Verbenaceae
81.	***Vitex nigundo*** L**.**	Lakki Gida	Verbenaceae
82.	***Ziziphus oenoplia*** L**.**	Karimulle Hannu	Rhamnaceae
83.	***Ziziphus rugosa*** L**.**	Bilimulle Hannu	Rhamnaceae

II. Introduced species

No	Name	Common Name	Family
1	***Chromolina odorata*** L.	Gurage gida	Apiaceae
2	***Gliricidea sepium*** Jacq.	Gobbarada gida	Papilionaceae

III. Rare and endemic Angiosperm species recorded

No	Name	Family
1.	***Nothapodytes nimmoniana*** J.Grah**.**	Icacinaceae
2.	***Syzygium zeylanicum*** *L.DC***.**	Myrtaceae
3.	***Sarcanthus pauciflorus*** Wight	Orchidaceae
4.	***Rhynchostylis retusa*** (L.) Blume	Orchidaceae
5.	***Pholidota pallid*** L**.**	Orchidaceae
6.	***Oberonia recurva*** L.	Orchidaceae
7.	***Hopea ponga**** Dennst (Endangered)	Dipterocarpaceae
8.	***Flacourtia montana*** J. Grah.	Flacourtiaceae
9.	***Garcinia gummi-gutta*** L.	Clusiaceae

10.	***Garcinia indica*** L**.**	Clusiaceae
11.	***Dalbergia tamerindifolia*** Roxb.	Mimoseae
12.	***Derris scandens*** Roxb**.**	Leguminoseae
13.	***Ficus hispida*** L**.**	Moraceae
14.	***Elaegnus conferta*** Roxb**.**	Elaegnaceae
15.	***Curcuma neilgherrensis*** Wight**.**	Zingeberaceae
16.	***Cyathea gigantean*** Wall.	Cyatheaceae
17.	***Cymbidium bicolor*** Lindl.	Orchidaceae
18.	***Crinum viviparum*** Lam.	Amaryllidaceae
19.	***Cinnamomum malabatrum*** Burm**.**	Lauraceae
20.	***Acampe premosa*** L.	Orchidaceae
21.	***Artocarpus heterophylla*** Lam.	Moraceae

Note: * IUCN Red Listed Species

(Tthe data recoded by this investigator during 2010-11/ 2014-16)

Annexure-II

TABLE -2.

Typical riparian Angiosperm plant species recorded in riparian zones of streams in *Netavati* River *v*alley system.

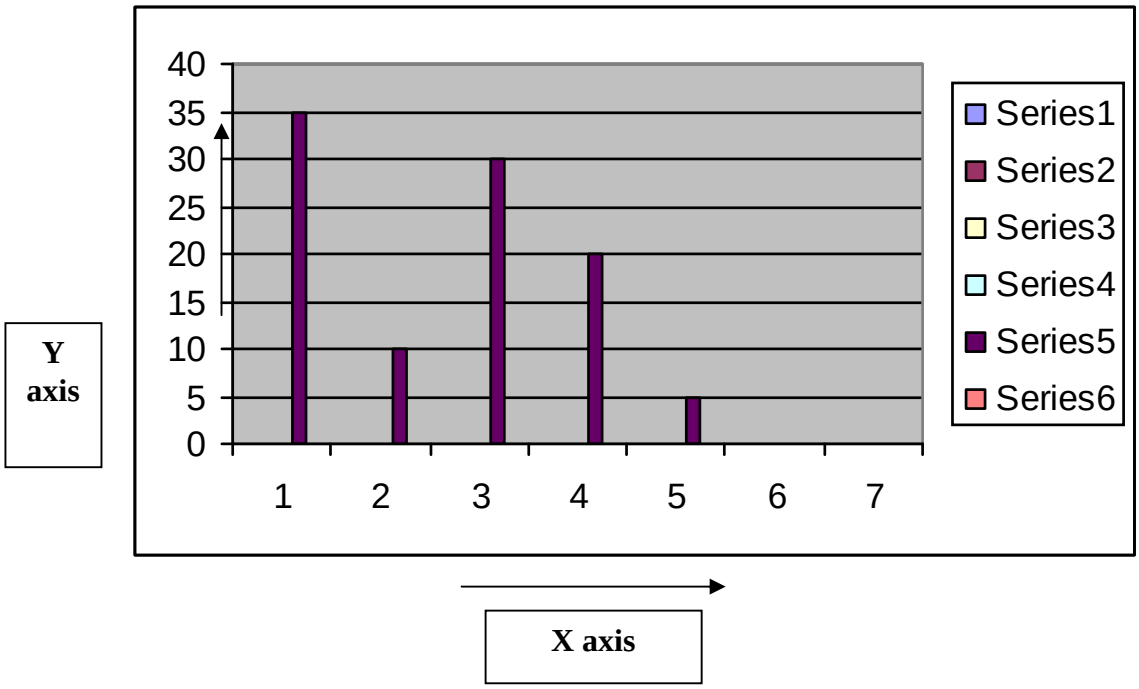
(In central *Western Ghats*, *Dakshina Kannada,* Karnataka, India).

No	Name	Family
1.	*Ochreinauclea missions* Ried.	Rubiaceae
2.	*Neolamarkia cadamba* Roxb.	Rubiaceae
3.	*Rotula aquatic L.*	Boraginaceae
4.	*Homonia riparia L.*	Euphorbiaceae
5.	*Actinodaphne bourdillonii* Gamble.	Lauraceae
6.	*Ochlandra scriptoria* Fischer.	Poaceae
7.	*Callophyllum inophullum* L.	Guttiferae
8.	*Callophyllum apetalum* L.	Guttiferae
9.	*Vitex leucoxylon* L.	Verbinaceae
10.	*Madhuca neriifoila* H.J.Lam	Sapotaceae
11.	*Syzygium cumini* L.	Myrtaceae
12.	*Holigarna arnotiana* Hook.	Anacardiaceae
13.	*Holigarna grahmii* Kurz.	Anacardiaceae
14.	*Cinnammomum riparium* Nees	Lauraceae
15.	*Mangifera indica* (wild)	Anacardiaceae

Note: The data recoded by Keshava, H. Korse,(2010-11/ 2014-16)

Graph - I

The principle characters governing the average water volume in the perennial river systems in the central *Western Ghats* region in Karnataka- the findings of preliminary studies.

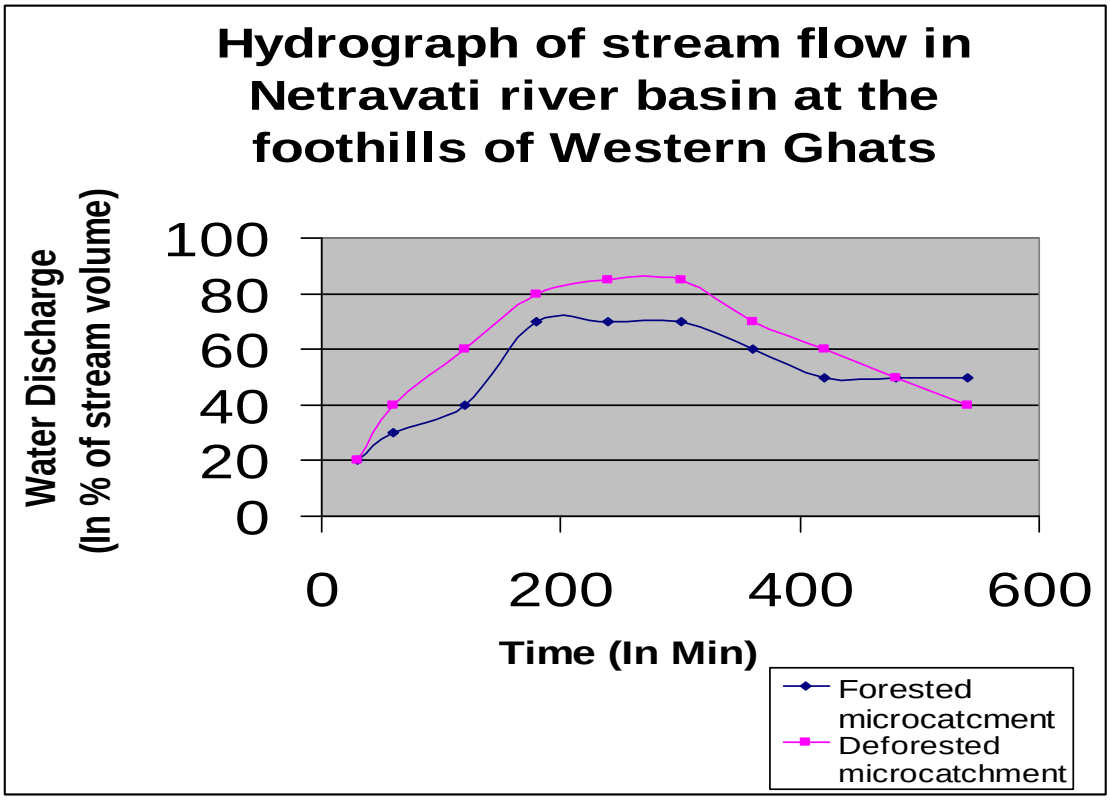


Index

No	Parameters (X axis)	Weightage (%) (Y axis)
1	Rainfall in the catchments	**35**
2	Catchments terrain	**10**
3	Vegetation type on the catchments	**30**
4	Vegetation type on the river bank	**20**
5	Edaphic character of the river bank & bed	**5**

Graph - II

Water discharge pattern in streams of *Netravati* river after first heavy rain in Monsoon.



GRAPH - III

Average monthly flow in *Netravati* River in comparison *with* *Aghanashini* River, which also flows through the foothills of central *Western Ghats* of India.

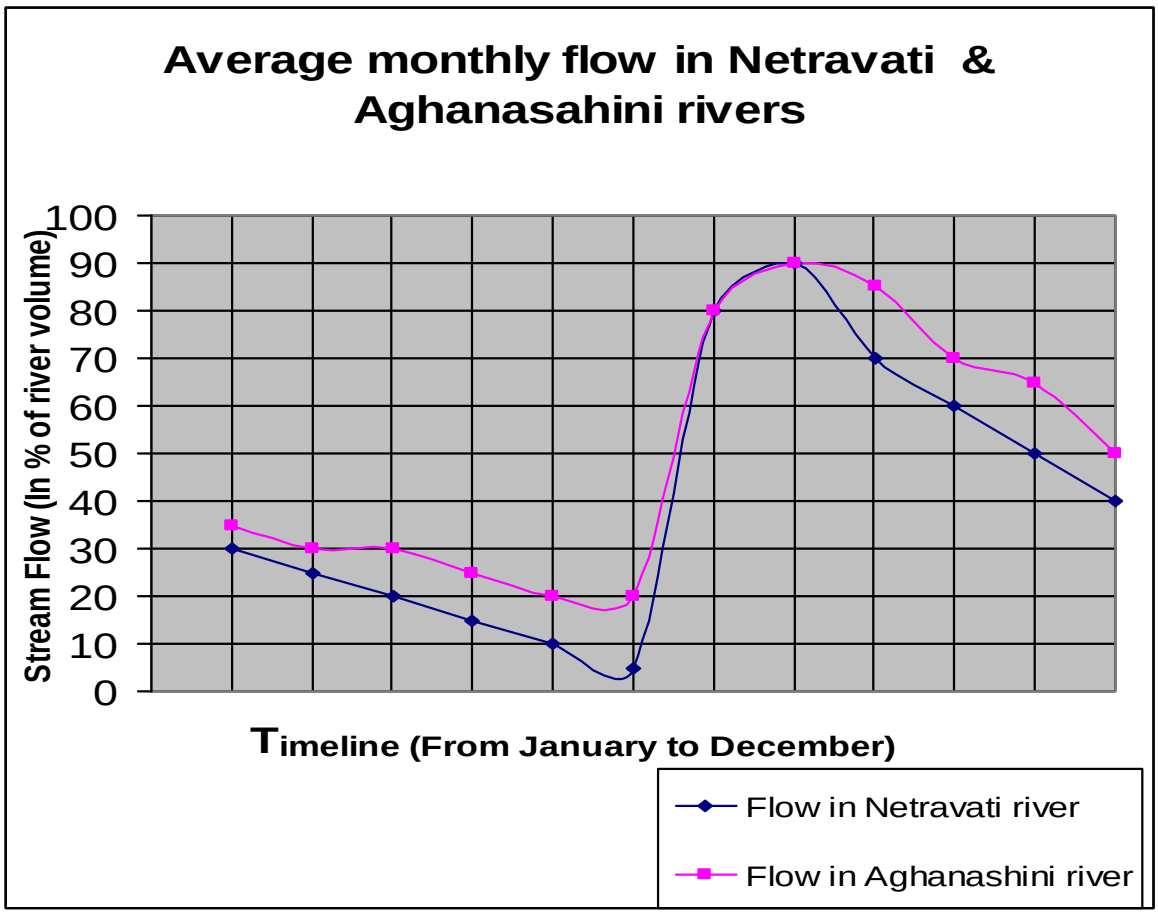
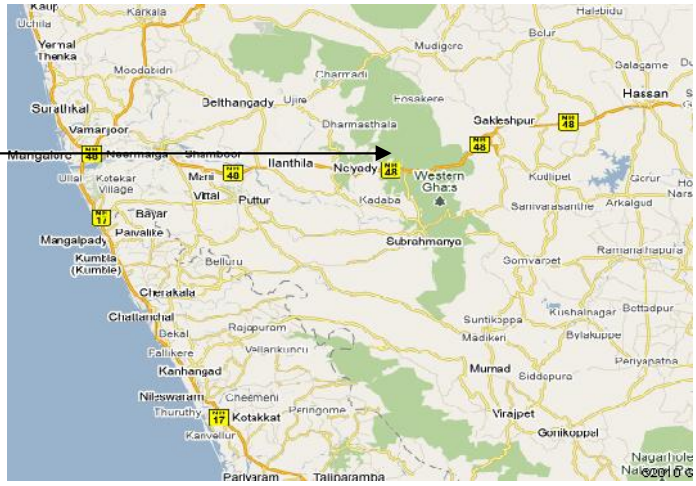
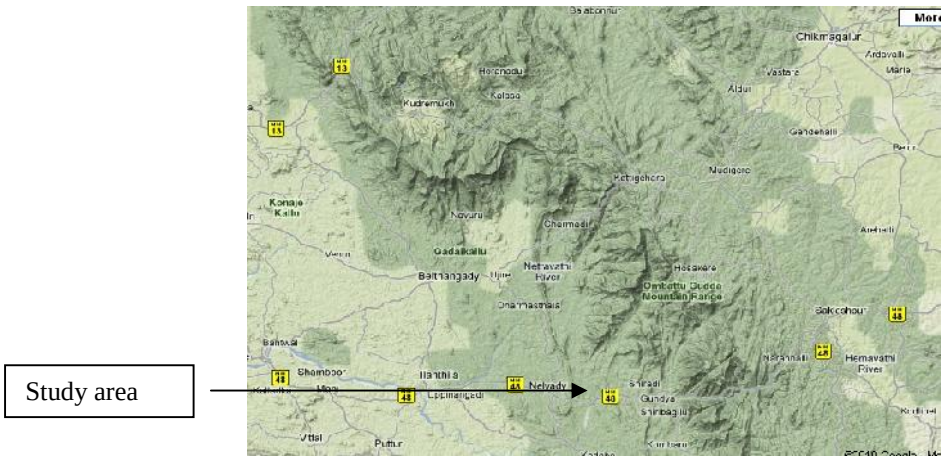


PHOTO PLATE-I

Maps of the study area



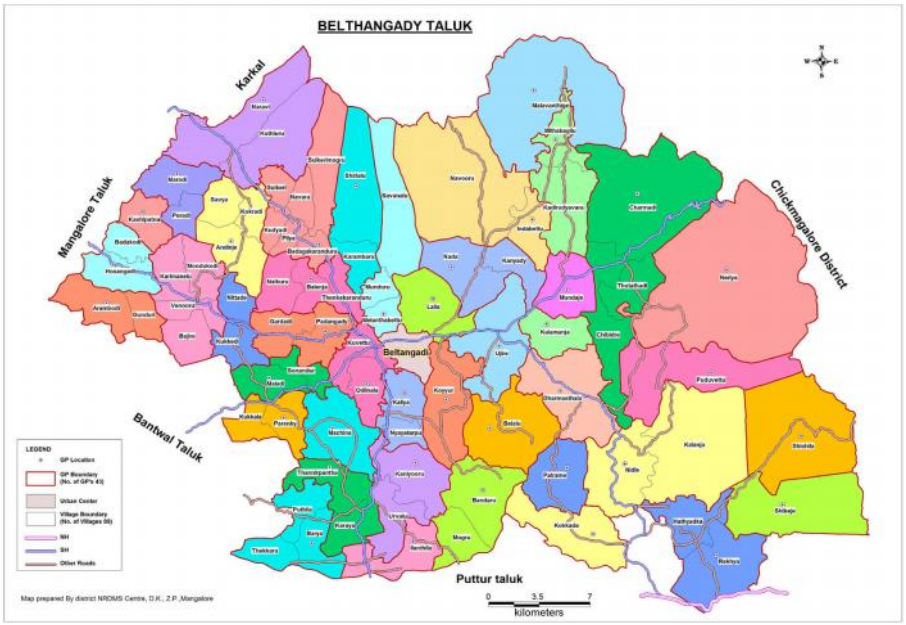
Map of the study area
(In *Belthangady* taluk of *Dakshina Kaada* District)



Satellite image of the study area
(In *Belthangady* taluk of *Dakshina Kaada* District, Courtesy: *Google* Inc.)

PHOTO PLATE-II

Revenue map of study area



The revenue map of Belthangady taluk of *Dakshina Kannada* district.

(The north east region this taluk forms the major catchments of the *Netravati* River and this study is carried out there)

PHOTO PLATE- III

Images of study area

	**Charmady hill range.** (It is in the border of Belthangady & Mudigere Forest Ranges, the prime watershed of *Netravati* River system.(Many I-order streams originate here)
	**Upper reaches of Netravati River** (Origin points of I- order streams)
	**The typical riparian zone as an ecosystem, in III-order streams**

	**The water flow during the post monsoon season** (III – order streams)
	**The riverbed flora (II –order stream)**
	**The river flow during non flooding season** (III-order stream)

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	**The upper catchment region of *Netravati* River**
	**The downstream of *Netravati* River, after reaching the coastal plain region, in Bantwal Tq, D.K. Dist., Karnataka**
	**The river bank zone of a II-order stream of *Netravati* River in *Western Ghats* zone.**

	**A natural flood barrier by *Rotula aquatica* Lour. at riverbed during post monsoon season in main stream of *Netravati* River in foothills of *Western Ghats* zone. (II –Order).**
	**The riverbed and bank zone during post winter season in the main stream of *Netravati* River in central Western *Ghats* of Karnataka. (III-order)**
	**The main stream of *Netravati* River (Beyond III-order*)* in early monsoon period in foot hills of *Western Ghats* zone.**

PHOTO PLATE – IV

Land Use Pattern

	**The common land used by farmers, often make the immediate catchment area of *Netravati* River in the foothills of *Western Ghats* zone.**
	**The horticultural orchards often make the immediate catchment area of *Netravati* River in downstream.**
	**Eroded common land being brought under watershed development techniques.** **(In Navoor village, Belthangady taluk).**

PHOTO PLATE-V

Some Riparian Angiosperm Species

Holigarna arnotiana Hook.

Calophyllum inophyllum L.

Neolamarckia cadamba **Roxb.**

Homonoia riparia **Lour.**

Mesua ferrea. **L.**

Madhuca neriifoila H.J.Lam

 ***Calophyllum apetalum* Willd.**	 ***Ventilago madraspatrtna***
 *Actinodaphne bourdillonii* Gamble.	